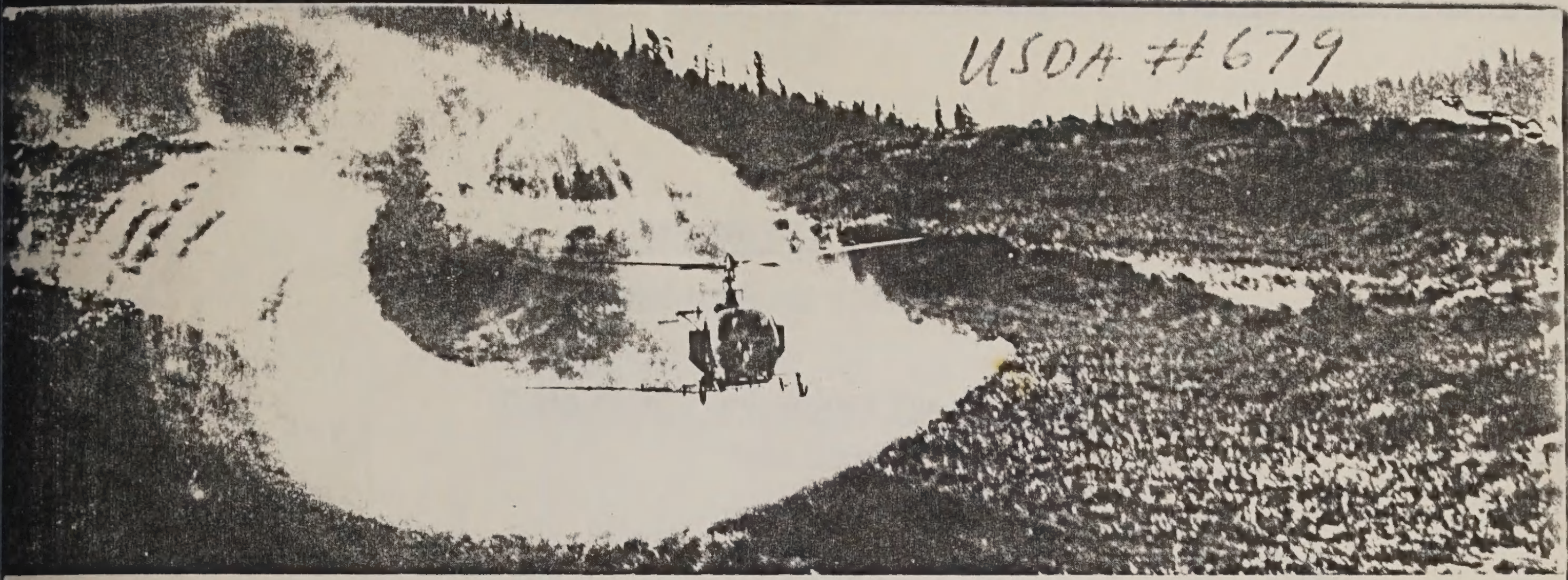
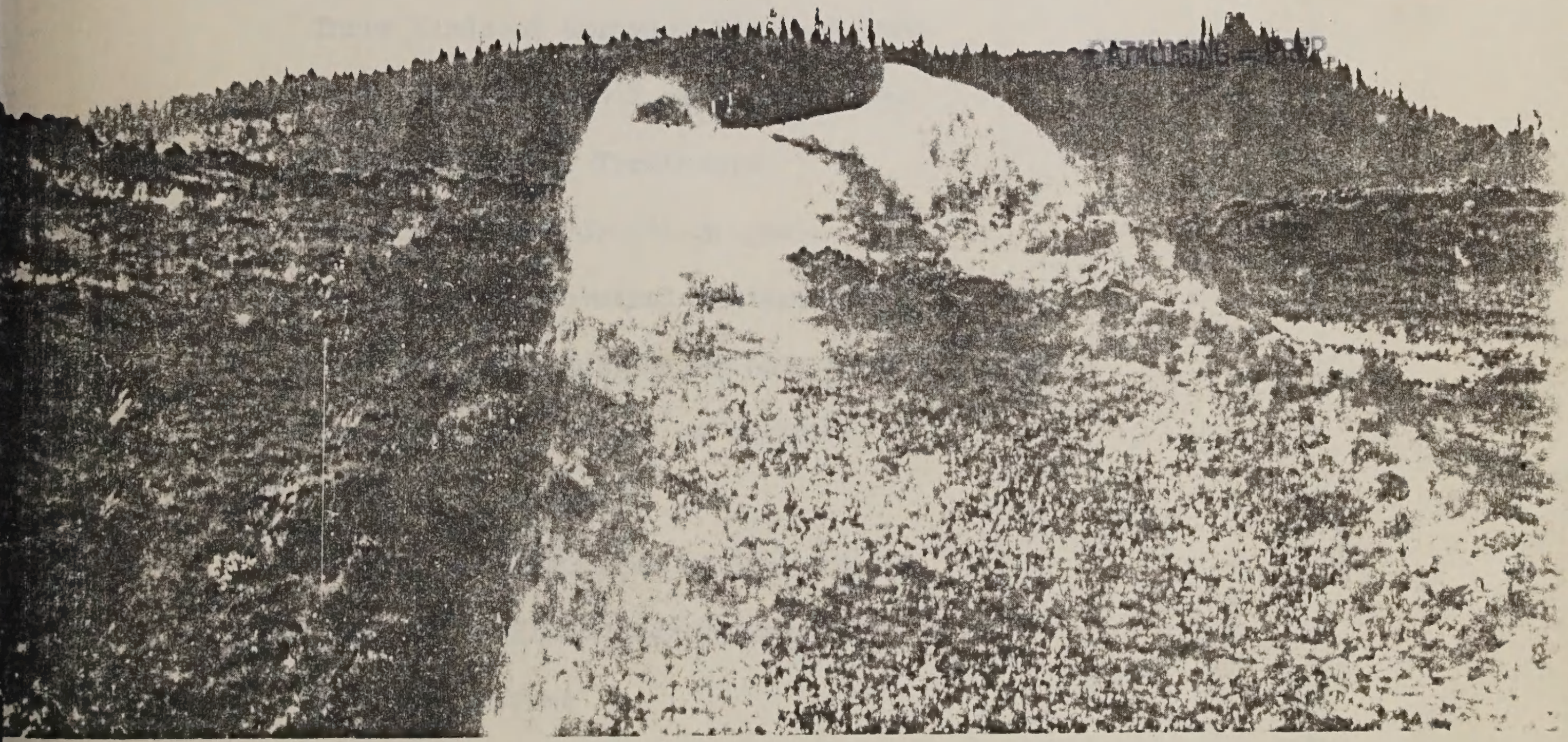


Use of Herbicides on Timber Plantations

Jay R. Bentley and Kenneth M. Estes



For In-Service Use

California Region and
Pacific Southwest Forest and Range Experiment Station
Forest Service - U.S. Department of Agriculture

San Francisco, California

September, 1965

REGION FIVE - PSW

USE OF HERBICIDES ON TIMBER PLANTATIONS

Third Report and Guides for Spraying

July 1965

Contents — Page

Contents Page

APPENDIX I

APPENDIX II

REGION FIVE - PSW
USE OF HERBICIDES ON TIMBER PLANTATIONS

Third Report and Guides for Spraying

STATUS OF STUDY

This report summarizes the conclusions and recommendations already discussed with many field personnel during the last year. We will welcome suggestions on changes in format and content that will make the material more useful before we put it out in handbook form.

The comprehensive administrative study was terminated at the end of fiscal year 1965 as planned. Limited tests are being continued, however, in connection with project work to keep the guides up to date. But most of the emphasis will be put into direct service to Forests and Districts as part of a sound and effective brush control program on timber plantations.

Final brush counts and evaluations will be made in 1965 and a brief report prepared for all studies started in 1962 and 1963 (table 1). Treatments are being continued in 1965 and succeeding years on certain plots sprayed in 1964 (table 2). A few project tests should be started to determine the results from periodic light applications of 2,4,5-T after planting of trees and from helicopter spraying at volumes of 5, 10 and 20 gallons per acre.

BRUSH CONTROL BENEFITS AND OBJECTIVES

Effective herbicide treatments are needed to control brush regrowth on most timber plantations in California. Although adequate tree stocking and eventual overtopping of the brush seem assured on most of the favorable sites where the brush was thoroughly removed by bulldozing, follow-up chemical control of brush in most cases will promote faster tree growth and thus shorten the rotation interval. Another need is the effective use of herbicides in preparing sites for planting to kill brush without expensive bulldozing and thus reduce the total costs of establishing and caring for timber plantations. These and other benefits can come from using herbicides as part of an aggressive brush control program.

Table 1.--List of individual studies to be evaluated in 1965.

No.	Location	Important species	Years sprayed	Factors Tested
SPI	Foresthill R.D. Tahoe N.F.	Bear clover Deerbrush Manzanita	1962 1963 1964	Nine method-year combinations, 6 chemical mixtures (54 treatments).
SPI	Mineral R.D. Lassen N.F.	Chinkapin Bitter cherry Manzanita	1962 1963 1964	As above
SPI	Sacramento R.D. Shasta-Trinity N.F.	Sierra plum Manzanita Snowbrush	1962 1963 1964	As above
SP2	Almanor R.D. Lassen N.F.	Chinkapin	1962	Mistblower broadcast, 1 chemical, 3 rates, 2 vols. (6 treatments)
SP3	Ukonom R.D. Klamath N.F.	Tanoak	1963	One chemical, 2 rates, 4-method-volume combinations, 4 dates (32 treatments)
SP6	Magalia R.D. Lassen N.F.	Chinkapin	1963	Four method-volume combinations, 2 chemicals, 3 dates (24 treatments)
SP6	Quincy R.D. Plumas N.F.	Bitter cherry	1963	As above
SP7	Magalia R.D. Lassen N.F.	Chinkapin	1963	Two hand spray methods, 1 chemical, 2 concentrations, 3 dates (12 treatments)
SP7	Quincy R.D. Plumas N.F.	Bitter cherry	1963	As above
SP8	Tish Tang R.D. Six Rivers N.F.	Tanoak	1963	Mistblower, 6 chemical mixtures, 3 dates (18 treatments)

Table 1.--List of individual studies to be evaluated in 1965(cont)

No.	Location	Important species	Years sprayed	Factors tested
SP10	Tish Tang R.D. Six Rivers N.F.	Tanoak	1963	Backpump, 5 chemical mixtures, 3 dates (15 treatments)
SP12	Mineral R.D. Lassen N.F.	Chinkapin	1963	Broadcast, 10 chemical-rate comb., 2 carriers (20 treatments)
SP14	Six Rivers N.F.	Tanoak	1964	Three hand spray methods, 2 chemicals, 5 dates (10 treatments)
SP16	Foresthill R.D.	Deerbrush	1964	Broadcast, 5 chemical-rate combinations, 1 date (5 treatments)
PC10	Almanor R.D.	Whitethorn	1962	Mistblower broadcast, 2 oil-vol. comb., 1 chemical, 5 rates; plus 2 oil vol. comb. (12 treatments)
PC11	Mineral R.D. Lassen N.F.	Chinkapin	1962	Mistblower broadcast, 4 vol.-oil comb., 1 chemical-rate comb. (4 treatments)
PC36	Sacramento R.D. Shasta-Trinity N.F.	Snowbrush Manzanita Sierra plum	1962 plus 1964	Two methods, 12 date-chemical comb. (24 treatments)
PC37	Sacramento R.D. Shasta-Trinity N.F.	Bitter cherry Snow brush Manzanita	1962	Broadcast, 2 volumes, date-chemical comb. (20 treatments)
PC38	Sacramento R.D. Shasta-Trinity N.F.	Chinkapin Manzanita	1962 plus 1963	Broadcast, 2 volumes, 2 dates, 2 chemicals, 3 rates (24 treatments)
PC42	Sacramento R.D. Shasta-Trinity N.F.	Bitter cherry Manzanita	1963 plus 1964	Broadcast, 1 chemical, 4 rates, 3 dates (12 treatments)

Table 2.--Studies that require spraying in 1965--final evaluation in 1966 or later

No.	Location	Important species	Years sprayed	Factors tested
SP11	Quincy R.D. Plumas N.F.	Bitter cherry	1963 1964 1965	Nine method-year comb., 1 chemical mixture (9 treatments)
SP13	Sacramento R.D. Shasta-Trinity N.F.	Manzanita Sierra plum	1964 1965 1966-1967	Three year comb., 3 chemicals, 3 rates (27 treatments)
SP15	Sacramento R.D. Shasta-Trinity N.F.	Manzanita Sierra plum	1964 1965 1966-1967	Various year-date comb., and chemicals

Brush control on plantation areas usually has several broad objectives. But these objectives differ in detail between the pine zone and the Douglas-fir zone. Earlier and more complete control of brush is needed in pine plantations to prevent overtopping of the trees and to reduce competition for soil moisture. In contrast, some shading by shrubs may benefit young fir seedlings, and competition of shrubs for moisture is not considered as so critical.

BROAD OBJECTIVES

A. Maintain tree growth at 80-100 percent of site potential

Pine zone

1. Prevent overtopping of pines at all ages; establish early control of all competing vegetation.
2. Hold down competition of brush for soil moisture; reduce shrub stand to lowest practical level.

Douglas-fir zone

1. Eliminate or reduce competition from hardwood trees.
2. Periodically release firs from overtopping shrubs.

B. Facilitate future silvicultural operations

1. Develop open forest conditions where feasible, especially in the pine zone.

C. Reduce fire hazards

1. Prevent development of continuous dense brush stands loaded with dead heavy fuel, especially in the pine zone.
2. Separate tree crowns from brush fuels as quickly as possible.
3. Eliminate brush fuel indefinitely on pre-planned fuel-breaks within and around plantation areas.

D. Enhance game habitat

1. Keep brush open, low and usable as browse by game animals or livestock.

2. Develop vegetation patterns that provide cover, edge, browse and forage.

SPECIFIC CHEMICAL CONTROL OBJECTIVES

Each chemical control technique--which may consist of one or several individual applications--will have a specific objective. The technique, and the objectives, will be different for the pine zone as contrasted to the fir zone, and for a fuel-break as contrasted to the bulk of a plantation area. Each recommended technique will have one of four objectives, as follows:

Objective 1--Reduce the overall brush cover to an open, spotty stand of stunted plants. Acceptable degree of control is the lowest level that can be economically obtained.

Objective 2--Eliminate almost all woody fuel for an indefinite period. Full brush control is required regardless of cost, as on fuel-breaks.

Objective 3--Release any overtopped conifers. Increased tree growth at reasonable cost is required.

Objective 4--Control hardwood tree sprouts. Elimination of serious competition is needed, the cost depending on density of the hardwoods.

BRUSH CONTROL CONCLUSIONS

Our brush control recommendations are based on a series of current conclusions drawn from all available information, including the literature, unpublished results from our past studies in various brush types, current project-scale work, other field observations, and interviews.

The conclusions and the recommendations will be modified as new information becomes available. The following brief statement of conclusions will be supplemented later by more detailed reports of results and conclusions from individual studies.

USE CHEMICAL TREATMENTS ON PLANTATIONS

This first general conclusion assumes that holding of brush at the desired level will require control treatment at some stage, or stages, in establishing and caring for almost all plantations.

Chemical treatment rather than some other method of brush control is recommended because--

> Chemical spraying often is the only feasible method.
>
> It usually is the cheapest method.
>
> It gives more complete brush control than mechanical treatment which tends to stimulate establishment of new plants.

THREE KINDS OF SPRAYING MAY BE NEEDED

Two kinds of chemical treatment may be used before planting of trees, plus spraying after trees have been planted, as follows:

Fuel-preparation spraying--to desiccate brush leaves and twigs, or to kill entire plants, ahead of prescribed broadcast burning.

> It is the only feasible method for preparing brush fuels on areas where bulldozers cannot be used to crush the brush.

> Spraying of crushed brush also may be needed, especially in preparing block borders for easier ignition.

Site-preparation spraying--to reduce brush regrowth after the brush has been removed by bulldozing or burning and before trees have been planted.

Spraying can be timed for best brush kill without concern for damage to trees--the job can be done more effectively and at lower cost than spraying after trees have been planted.

> Site-preparation spraying is particularly needed on areas cleared by broadcast burning or shallow dozing because of the typical fast brush regeneration.
>
> It also is needed on bulldozed areas if brush sprouts or rapidly growing seedlings will soon develop a full brush cover.
>
> It is least needed in situations where brush reinvasion typically occurs slowly over a period of years.

Plantation-care spraying (release spraying)--to control brush regrowth after trees have been planted. Spraying is timed to avoid tree damage and to obtain best possible brush control.

> In pine plantations, the spraying should be a continuation of chemical control started before planting, or the release spraying should be started as soon as possible after planting and continued until brush control is adequate.
>
> In fir plantations, release sprayings should be applied as needed. Hand spraying of tanoak or other hardwoods, often started before planting, can be continued if needed after planting.

SPRAY BRUSH REGROWTH AT AN EARLY AGE

A basic principle of weed control--equally applicable in agriculture and forestry--is to treat weed plants when they are small and most vulnerable.

Spraying of brush regrowth usually should be started during the first or second season after initial removal of the old aerial parts. At this time the plants can be killed with minimum chemical and spray volume.

New brush seedlings are highly vulnerable to foliar sprays. They can be eradicated with one light spray as soon as all of the current crop has emerged.

> The small aerial parts are easily covered, and root systems are poorly developed.
>
> Success may be greatly reduced after the seedlings have grown for two or more years and have developed dense crowns, tough tissue, and full root systems.

Small brush sprouts are killed more easily than large sprouting plants.

> Small crowns are readily covered, tissues are more easily penetrated by chemicals and translocation distance is shorter.
>
> Root systems and food reserves often are at a low development stage soon after initial brush removal.
>
> But new sprouts can be too small. One full growing season usually is required to develop adequate topgrowth for effective spraying.

Our recommended spray techniques have been developed for use on small brush regrowth. The treatments can be applied to larger, older brush plants, but good brush control is less assured and the costs will be greater.

REPEAT THE SPRAY TREATMENTS

Spraying during two or more years has proved to be the key to consistently successful brush control under many different situations

Preliminary results from our study plots on timber plantations indicate that the number of times spray is applied has more effect in eradicating brush than does the kind or rate of herbicide that is applied.

Repeated spraying acts in several ways to bring about more effective brush kill:

> Plants missed by one spray job--and some always are missed--can be covered during the next spraying.
>
> Plants weakened by one spray are highly vulnerable to the next spray. Sometimes reduction of dense crowns alone is a key factor in obtaining a good kill from the second spray.
>
> New seedlings established after the first spray job are killed by later spraying--a most important factor in controlling brush in timber plantations because new seedlings typically are established for years after initial clearing.
>
> The odds of poor results from unfavorable weather or plant growth conditions are reduced if the spray treatments are spread over two or three years.
>
> Minimum chemical treatment can be recommended for each application if follow-up spraying is planned. Thus, three sprays may be applied as cheaply as two.

Three spray treatments, including site-preparation and plantation-care (release) spraying, should be planned. The three sprays need not be in consecutive years, but for the denser stands of sprouting brush at least two consecutive sprays appear needed.

Three treatments may extend over a period of 3 to 5 years, or longer. However, spraying can be terminated at any time if full brush control has been obtained with less than three treatments.

Dense stands of new seedlings should not be allowed to grow more than two years before spraying.

SPRAY AT PROPER PLANT GROWTH STAGES

Another basic principle of weed control is to apply chemical sprays at a susceptible stage of plant growth. But this stage is most difficult to recognize, describe, and predict.

In actual practice, efficient project planning requires that recommendations be made far in advance of the date when spraying should be done.

Limited opportunity exists for adjusting the spray date to the best growth stage of one or two key species.

Fortunately, the period for effective spraying is relatively long for a stand of small brush seedlings and sprouts on recently cleared plantation areas. The plants do not extract soil moisture rapidly; they continue to grow through the rainless season. Adequate amounts of chemical will kill the plants even though spraying may not be done at the most susceptible stage for certain species.

However, the effective spray period shortens each year as brush regrowth becomes denser, larger and more mature. Moisture stress occurs during the dry season, and effectiveness of chemical sprays is reduced.

A guiding principle is to spray brush regrowth when it is still producing new twig growth, but before it is subject to extreme moisture stress and the leaf tissues have hardened.

> Seedlings can be sprayed any time after all of the current crop has emerged in early summer.
>
> But delay spraying of sprouts and mixtures of sprouts and seedlings until near the end of the active growth period--in July, August, or early September. Spraying too early will produce resprouting the same year.
>
> Spray deciduous species, such as bitter cherry, before leaves start to turn color in early fall.

> Delay plantation-care (release) spraying until terminal buds on pines are fully formed and hardened.
>
> Apply foliage sprays before freezing weather in late fall.

Proper timing for effective control of small brush plants has been easily accomplished in young pine plantations without appreciable tree damage. Adequate control of the mature evergreen brush species in older plantations also appears possible. But proper timing may not be possible for control of mature deciduous plants that flower and fruit early in the season in old pine plantations.

Suggested spray dates for different situations are shown in the section on recommended spray techniques.

USE EFFECTIVE CHEMICAL MIXTURES

The cheapest chemicals that are effective and safe should be used in adequate amounts.

Chemicals--2,4-D and 2,4,5-T are relatively cheap systemic herbicides that will control most of our brush species.

Other chemicals, some of which are very expensive, eventually may prove useful for specific problem species, but are not recommended at present for widescale use.

> Formulations of two low volatile esters of 2,4-D and 2,4,5-T (butoxy ethanol ester and prophylene glycol butyl ether ester) have been adequately tested for safe use in plantations. Other ester formulations may prove effective on brush but should not be sprayed on pines until thoroughly tested.
>
> Both 2,4-D and 2,4,5-T are effective on most of our brush species, although some species are more susceptible to one or the other. A "brushkiller" mixture of the two chemicals usually is used for site preparation spraying. Mixtures now being used contain a high proportion of 2,4-D which costs only half as much as 2,4,5-T.

> But 2,4,5-T is used alone for broadcast release spraying on pine plantations because the pines are less tolerant to 2,4-D.

Rates--The amount of chemical required in each application depends on age and size of brush plants and on the number of applications to be made:

> First-year seedlings have been eradicated by a single broadcast spray at a light rate of 2 pounds, acid equivalent, per acre.
>
> Sprouts and older seedlings have not been greatly reduced by a single light application but in some cases have been adequately controlled by three light sprays.
>
> A heavier initial application of 4 to 6 pounds, a.e., per acre with light follow-up sprays gives more assured brush reduction.

In plantation-care (release) spraying, the 2,4,5-T has been applied at 2 to 4 pounds, acid equivalent, per acre. In most cases the heavier rate has produced only limited tree damage but under certain conditions the damage has been too great.

A rate of 2 to 3 pounds, a.e., per acre is recommended for initial spraying of young brush regrowth in first-year pine plantations. This lower rate also can be used for follow-up spraying in plantations after an initial spray has reduced the brush growth.

The higher rate of 3 to 4 pounds, a.e., per acre can be applied as an initial spray on brush regrowth that is two years old, or older, provided that local experience shows this rate can be safely used. If the higher rate is questionable, apply the initial spray at a lower rate and the follow-up sprays at a rate which experience indicates is both safe and effective.

Our observations on spraying pine plantations with 2,4,5-T at 4 pounds, a.e., per acre are as follows:

1. Ground-rig broadcast boom spraying at this rate during three years on considerable acreage on the Sacramento District, Shasta-Trinity, has produced little or no damage to pine seedlings from 1 to 5 years of age, provided the spraying was done in late August or in September. Only limited damage occurred on plots sprayed at 6 pounds per acre. But the 4-pound rate appeared to be near the safe maximum for project spraying.

2. Helicopter application of 4 pounds 2,4,5-T per acre on extensive acreage in 1964 on the Shasta-Trinity and Klamath has produced negligible tree damage to date. The chemical was applied by double flying a total volume of 20 gallons per acre, with 10 gallons per acre applied in each flight. Care must be taken to obtain uniform application if the 4-pound rate is applied.

3. Helicopter applications in 1963 on the Shasta-Trinity with 4 pounds 2,4,5-T in 8 gallons total emulsion per acre applied by single flying produced more tree damage than is desired.

4. Two helicopter applications of 4 pounds 2,4,5-T in 20 gallons of emulsion per acre, double flown, on the Stanislaus produced excessive tree damage. One application in 1963 was on 6-year-old pines, and the other in 1964 was on 2-year pine seedlings. The damage from chemical on both plantations was compounded by the heavy damage from cold weather in 1964-65, which caused losses on both sprayed and unsprayed areas.

The causes for greater susceptibility of pines on the Stanislaus are not known but are assumed to be latitudinal effects on growth stage of the pines. Differences in the seedling stock also may be a factor--the seedlings may be inherently less resistant to 2,4,5-T.

Obviously, more testing of chemical rate and date of application is needed on pine plantations in the southern half of the Westside pine zone. At present we suggest that release spraying proceed with caution in this part of the zone. Use the lower rates of 2,4,5-T and delay spraying until the pines are at their lowest stage of growth activity.

USE EFFICIENT, ADAPTED METHODS OF APPLICATIONS

Broadcast spraying of a chemical mixture uniformly over an area generally is the most efficient application method. It has several advantages over individual-plant application (hand spraying):

> Broadcast spraying eliminates most small seedlings, many of which will be missed on an area sprayed by hand.
>
> Broadcast application covers large areas rapidly within the period of brush susceptibility.
>
> It is relatively cheap--approximately $3-$5 per acre compared to several times this amount for hand spraying of semi-dense or dense stands.

Uniform coverage is necessary for effective brush kill with minimum chemical rates. It is absolutely essential in broadcast spraying over young pines that may be damaged by overlapped swaths or uneven application within swaths.

Helicopter boom sprayers are adapted on all terrain and over trees of all sizes. They give good coverage of windrows.

> Double flying, with half the spray material applied in each flight, gives best coverage of the brush. It is vital in reducing damage to young pines.
>
> Care must be taken to avoid drift onto adjacent areas.

Ground-rig boom sprayers give excellent coverage on suitable terrain, but cannot be used over trees more than 2 to 3 feet in height. Windrows are difficult to spray with a ground-rig.

> Care must be taken to overlap the swaths properly.
>
> Chemical loss is minimal, resulting in excellent brush kills.

Shielded-row boom sprayers can be used over small trees (1-3 years old) in machine-planted rows.

> Combined with hand spraying between trees it can give excellent brush control.
>
> It is limited by slow progress and fairly high cost.

Ground-rig off-set nozzle sprayers, and similar rigs with no boom, do not give uniform coverage and are not recommended in most cases.

> However, if no other method is available, such rigs can be used for site-preparation spraying with high volume (50-100 gallons per acre) and moderate to heavy chemical rates.
>
> Do not use this method of application for plantation-care spraying over young pine trees because of the uneven application.

Mistblower broadcast sprayers also give uneven coverage, especially on large seedlings or sprouts with dense crowns.

> If no other method is available, mistblowers can be used for broadcast site-preparation spraying if the swaths are kept narrow.
>
> Never spray over young pines because of the excessive damage from the fine mist.

Individual-plant spraying is best used for control of hardwood sprouts, such as tanoak. It also is adapted for follow-up control where broadcast spraying has thinned the brush stand and left mainly the hard-to-kill species.

> It is too costly for widespread use in fairly dense regrowth, except in locations with a cheap labor supply available. It may be adapted on small areas of high value.
>
> Brush plants should be small, especially on planted areas where trees can be damaged by spraying of large brush plants.

Good training and careful supervision are essential for successful hand spraying.

Backpack mistblowers are well adapted for individual-plant spraying of large clumps of sprouts with dense crowns.

Backpumps or power sprayers are best used on small plants. The power sprayer is more efficient on terrain where it is well adapted.

APPLY ADEQUATE VOLUME OF EMULSION

Adequate volume is needed for good coverage of all plants. Tests are still underway to determine the minimum volumes required for different methods of application on brush regrowth of different sizes.

Ground-rig boom spraying mainly has been done with a volume of 20-30 gallons per acre, which can be readily applied.

Cost of water hauling is nominal at most locations.

However, if supplying water is a problem the volume can be reduced to about 10 gallons per acre.

Helicopter boom spraying on plantations mainly has been done at 20 gallons per acre, but recommended volumes have been reduced to speed operations and lower costs.

A total vomume of 10 gallons per acre of emulsion is recommended for all site-preparation spraying, and for plantation-care spraying with 2 or 3 pounds per acre 2,4,5-T.

The total is increased to 15 gallons per acre for plantation-care spraying with 4 lbs of 2,4,5-T. Volume is increased because a test with ground-rig spraying indicated that increasing volumes--thus increasing the ratio of water to chemical--reduced tree damage when near maximum chemical rates were applied.

Carriers for different emulsions also are being tested.

> In site-preparation spraying, light diesel oil at one gallon per acre is added to the emulsion to improve spreading and penetration of chemical on the leaf surface. Limited tests with different proportions of oil in the emulsion have not shown conclusive differences in brush kill.
>
> In plantation-care spraying, only water is added to the chemical formulation because oil in excess amounts can damage pines. However, ground-rig boom spraying with one-half gallon diesel oil per.acre in the emulsion did not materially damage pines if the chemical was applied at no more than 4 pounds, a.e. per acre.

More testing is needed to determine the relative effects on brush and conifers from adding various surfactants to the emulsions.

More testing also is needed with thickened emulsions, such as inverts, to determine effects on both brush and conifers. The thick emulsions may prove valuable to prevent drift outside of sprayed areas, or for better coverage where helciopter spraying may have to be done from considerable height because of snags or other obstructions.

BRUSH CONTROL SITUATIONS

Some factors that obviously influence the brush control problems on timber plantations are: elevation, temperature, precipitation, soil, terrain, rock outcrop, original vegetation type, method of brush removal, dominant brush species, nature of regrowth (seedlings or sprouts), age and size of regrowth, its density, the year of tree planting, and the year of initial spray. Each factor can be subdivided, making millions of possible combinations if no correlation exists between factors. Fortunately several are closely correlated. Even so, consideration of all possible situations is not possible in practical spray application.

We are using a very simple classification of brush control situations based on stand continuity and density of small

seedlings and sprouts during the first two years after brush removal, and on the changes expected during the following years if the small brush regrowth is not controlled. For example, the original small seedlings probably will become established and may grow to be large plants before spraying is started. The sprouts also will increase in size. The overall brush stand increases in size and density and in resistance to control over the years. Thus, brush control recommendations must be changed if the brush stands start to mature before the initial spraying.

The classification of situations is based on the following definitions of terms:

Small seedlings are new brush plants--usually one or two years old with open crowns and limited root systems--the age and size of plant most easily killed by spraying. Some seedlings may develop dense crowns and grow out of this stage in the second year, or a few may remain small and relatively susceptible in the third year of growth.

Large seedlings are those which have developed dense crowns, strong root systems and hardened tissue. They become more resistant each year, and by about the fifth year are similar to mature plants.

Sprouts are plants originating from buds on crowns, or roots, or rhizomes, usually growing from a full root system containing food reserves. They commonly are resistant to control. Bulldozing may break up the root system and make the sprouts more susceptible to control for a few years, as often is the case with bitter cherry and other Prunus species. Sprouts are most susceptible to spraying during the first two years when the crowns are not fully developed and contain a high proportion of tender tissue.

Year 1 refers to the first season of brush regrowth after clearing. It is the next calendar year after brush has been removed by burning or bulldozing during summer or fall. But it is the same calendar year as the brush removal year if the brush has been removed in late winter or spring and new sprouts develop before summer.

Planting done immediately after clearing in late winter or spring is in year 1. It also is in year 1 if done the next spring after brush removal in summer or fall.

SIMPLE CLASSIFICATION OF SITUATIONS

No. 1--Spotty stand, few small seedlings and a few sprouts in years 1 and 2. Slow invasion is expected.

Generally not considered a brush control problem. Early spraying is not needed. A release spraying may be considered justified after several years, but follow-up sprays probably will not be.

No. 2--Thin, uneven stand of small seedlings in years 1 or 2; few sprouts. Fairly slow to rapid invasion may occur.

Often not recognized as a control problem, but close observation will show the seedling stand. Control will become more difficult and costly if initial spraying is delayed past the second year.

No. 3--Fairly continuous, often dense stand of small seedlings in year 1; few sprouts. Continued invasion expected.

The full brush stand in year 1 shows that site-preparation spraying is advisable. If already planted, do not delay the start of plantation-care spraying past the second year.

No. 4--Thin, uneven stand of sprouts in year 1; few to many small seedlings. Continued invasion expected.

Early control is needed to kill the sprouts. Site-preparation spraying is advisable; in any case do not delay the initial spray longer than necessary.

No. 5--Fairly continuous, often dense stand of sprouts in year 1; few to many small seedlings. Continued invasion may occur.

Site-preparation spraying is obviously needed; it is almost essential on burned-over areas of sprouting brush. Two site-preparation sprays are advisable, especially if an area contains chinkapin or similar tough species.

BRUSH CONTROL HERBICIDE RECOMMENDATIONS

Herbicide recommendations given strictly for individual brush species, as commonly done in the literature, cannot be used directly and have limited practical field use for several reasons:

> Species usually occur in complex mixtures that differ from place to place.
>
> The best treatment for a brush plant depends on whether it is a seedling or a sprout, small or large, with an open or dense crown.

Thus, we have given minimum attention to individual brush species even though differences in susceptibility between species are recognized and some modifications in treatment are suggested for certain species. For example, differences between deciduous and evergreen species require different timing of sprays. And the tougher species, such as chinquapin, possibly will require higher rates of herbicides.

Special techniques will be developed later for species not adequately controlled by present recommendations. At present, we have special recommendations for controlling sprouts of hardwoods, such as tanoak and black oak.

PINE PLANTATIONS

The basic recommendations are:

1. Plan for an initial spray and two follow-up sprays in most situations; the sprays to be applied over a period of 4 to 5 years, or longer.
    a. In situations No.1 and No. 2 where the brush seedling stand is thin or spotty and reinvasion is slow, one or two sprays probably will be adequate.
    b. However, in most situations at least two sprays will be required--to obtain optimum control per dollar expended in spraying.
    c. Three sprays will be needed where brush reinvasion is rapid, with vigorous growth of sprouts and seedlings--to gain adequate initial control and extend the control over 4 or 5 years, or longer.

2. Apply the initial spray (either as a site-preparation spray or a plantation-care spray) as soon as a full brush stand has become established; do not delay longer than necessary past this time.

    a. Spray dense stands of sprouts at the end of one full growing season, if possible.

    b. Spray dense stands of seedlings during the first or second growing season, if possible. Close observation may be needed to determine the presence of the seedling stand.

    c. If a brush stand already has grown past the first or second season, start the spray program as soon as possible.

3. Spread the sprays over the longest possible period of years--to maintain control of the continued reinvasion by new brush seedlings which commonly occurs for years after the original brush removal.

    a. Apply the first follow-up spray 2 years after the initial spray, <u>provided</u> that the initial spray produced the desired reduction of brush and that new seedlings have become established after the initial spray.

    b. Apply the first follow-up spray during the next year after the initial spray <u>if</u> the initial spray produced less than the desired control of vigorous species. Unfortunately, this often cannot be judged until near the end of the growing season--about the date when the next spray will be applied if it is needed that year.

    c. Delay the third spray until a new crop, or crops, of seedlings have become established, but apply the spray when most of the seedlings are no more than 2 years old.

4. Delay the year of planting to allow site-preparation spraying in situations where brush typically sprouts vigorously during the first year after clearing; also advisable on areas with dense stands of seedlings during the first year.

    a. Always apply at least one site-preparation spray on areas cleared by wildfire or prescribed broadcast burning. Two sprays have been recommended, but we hope to define conditions under which only one is necessary.

    b. Site-preparation sprays are advisable on bulldozed areas if experience has shown that brush reinvasion will be rapid and plant growth vigorous.

   c. Site-preparation spraying on many bulldozed areas is not so essential now that we have methods for adequate control of young brush plants after trees have been planted, provided the plantation-care spraying is started before brush regrowth is more than two years old. Such early control is especially important for deciduous species such as bitter cherry.

5. Use relatively light herbicide treatments if the initial spray is applied on small brush regrowth and three sprays are planned. Total cost can be no more than for two heavier applications.

   a. Apply 2 to 3 pounds, acid equivalent, per acre for the initial treatment; also for each follow-up treatment if satisfactory brush control is being obtained.

   b. For the initial site-preparation spray, increase the rate to 4 pounds per acre if sprouts are numerous or seedlings are large and vigorous. A heavy rate of 6 pounds can be used initially on the most vigorous stands of tough species such as chinquapin. Reduce the follow-up sprays to 2 to 3 pounds after satisfactory brush reduction has been started.

   c. For the initial plantation-care spray, increase the rate to 3 or 4 pounds of 2,4,5-T if brush regrowth is more than two years old or if younger growth is exceptionally tough and vigorous. But do not apply 4 pounds per acre in the central and southern Sierra pine zone until local experience shows this rate can be safely used.

6. Apply site-preparation sprays near the end of the active plant growing season, but ahead of extreme moisture stress on the brush. Spray before freezing weather in late fall.

   a. August spraying ordinarily is effective on young brush regrowth. But the spraying season can start in late June or July at lower elevations. About September 1 is an optimum date for spraying brush sprouts on areas burned during the preceding spring.

   b. Spray deciduous brush sprouts before the leaves start turning yellow, before September 15 in most situations. This is essential for control of small bitter cherry and Sierra plum sprouts.

7. Spray brush on planted areas soon after the pine buds have grown to full size and have hardened.

   a. Late August or September spraying is effective in northern California, but approximately September 15 is the latest date for best control of bitter cherry.

   b. Apply release sprays in the central and southern Sierra pine zone at the time when pine seedlings appear to be most dormant. The safest period has not been determined.

   c. Hand spraying on planted areas can be done before pine buds are fully developed if care is taken to prevent direct application on the trees. Or broadcast spraying can be done if the trees are protected with paper bags.

8. Use herbicide mixtures containing a high proportion of 2,4-D for initial site-preparation spraying, but apply 2,4,5-T alone for release spraying on planted areas.

   a. Repeated applications of 2,4-D on young brush regrowth can be more effective than 2,4,5-T per dollar expended. Some species, such as manzanita, are particularly sensitive to 2,4-D.

   b. Follow-up spraying with 2,4,5-T after trees have been planted will be most effective on the brush species most sensitive to 2,4,5-T.

   c. Brushkiller mixtures of 2,4-D and 2,4,5-T can be applied to brush on planted areas by selective placement that prevents direct application on the pine seedlings.

See table 3 for suitable spray mixtures. Use BK mixes for site-preparation spraying and T mixes for plantation-care (release) spraying.

Table 3.--Herbicide mixtures for brush control on pine plantations

Symbol	Herbicides[1] 2,4,5-T	Herbicides[1] 2,4-D	Diesel oil	Approximate cost chemicals	Approximate cost total[2]
	lbs.,a.e./ac.	lbs.,a.e./ac.	gal./ac.	dollars/ac.	dollars/ac.
BK2	0.50	1.50	1	2.25	5.50
BK3	0.75	2.25	1	3.25	6.50
BK4	1.00	3.00	1	4.25	7.50
BK5	1.25	3.75	1	5.25	8.50
BK6	1.50	4.50	1	6.25	9.50
T2	2.00	0.00	0	3.50	7.00
T3	3.00	0.00	0	5.25	8.50
T4	4.00	0.00	0	7.00	12.00

[1] Commercial formulations of low volatile esters (butoxy ethanol ester or propylene glycol butyl ether ester) usually containing 4 pounds, a.e., per gallon.

a. Mix herbicide and oil together for BK (brushkiller) mixes and add to sufficient water to make 10 gallons total emulsion per acre for helicopter spraying, or 20+ gallons per acre for ground-rig boom spraying of each mix.

b. Use 2,4,5-T formulation alone for T (2,4,5-T) mixes and add to sufficient water to make 10 gallons total emulsion per acre for T2 or T3 or to make 15 gallons per acre for T4 for helicopter spraying, or to make 20+ gallons per acre for ground-rig boom spraying of each mix.

[2] Includes application costs based on broadcast helicopter spraying at 10 gallons per acre double flown in two flights of 5 gallons each, except for T4 applied at 15 gallons per acre in two flights of 7.5 gallons each.

a. Total cost of ground-rig broadcast spraying is approximately the same but can be about $1.50 per acre less for T4.

b. Total cost of hand spraying depends on density and size of brush but will be approximately $12.50 to $25.00 for stands of 100 to 500 plants per acre, averaging about 18 inches or less in height. Use BK4 in 100 gallons of water for hand spraying.

Use of the most preferred herbicide treatments usually will require that the future brush regrowth situation be visualized at the time of brush clearing and adequate plans made at that time. Planning must be based on the expected brush control situation. The recommended treatments allow sufficient flexibility to fit most any situation that occurs. At the time that initial spraying of an area is first considered, select the recommended treatment of highest preference that can be used.

Alternate herbicide treatments, in order of preference, for each of five different brush regrowth situations on pine plantations are summarized in table 4.

Our recommendations allow the land manager to make certain choices as to years of spraying and herbicide mix to be applied each year. The final choice should be made just before the spray is applied, after the brush growth for the year can be evaluated and the best treatment decided. Contracts for commercial application can be written with sufficient flexibility to allow such choices. For example, the contract can be written to specify that a certain acreage is to be sprayed within areas designated on a map, but final selection of specific area, or areas, will be made at the time of spraying. The contract can specify a certain volume of spray material per acre, but the chemical rate can be adjusted as needed at the last minute if the Forest Service supplies the chemical. But sufficient chemical must be on hand to supply the maximum rate that may be needed, with any surplus carried over for future jobs.

Thus, the recommendations are purposely flexible to encourage development of the art of herbicide use, rather than strict adherence to a single recommended way of doing the job.

Table 4.--Brush regrowth situations and alternate planting and broadcast spray treatments for pine plantations.

Brush Regrowth Situation	Recommended Planting and Spraying								
			Herbicide application						
	Preference No.	Tree planting year	Initial		Follow-up		Follow-up		Cost per acre
			year	mix	year	mix	year	mix	
No. 1--Spotty stand, few small seedlings in years 1 and 2. Slow invasion expected.	(1)	1 or 2	4+	T2-4	--	--	--	--	$7-12
No. 2--Thin, uneven stand of small seedlings in years 1 and 2; few sprouts. Fairly slow to rapid invasion may occur.	(1)	1 or 2	2	T2	4	T2	5+	T2-4	$21-26
	(2)	1	1	T2	3	T2	4+	T2-4	21-26
	(3)	2	1	BK2	3	T2	4+	T2-4	20-25
	(4)	1 or 2	3+	T2-4	4+	T2	5+	T2-4	21-31
No. 3--Fairly continuous, often dense stand of small seedlings in year 1; few sprouts. Continued invasion expected.	(1)	2	1	BK4	3	T2	4+	T2-4	$22-27
	(2)	1	1	T2	2 or 3	T2-4	4+	T2-4	21-31
	(3)	3	2	BK4	4	T2-4	5+	T2-4	22-32
	(4)	1 or 2	2	T2	3	T2-4	4+	T2-4	21-31
	(5)	1 or 2	3+	T2-4	4+	T2-4	5+	T2-4	21-36
No. 4--Thin, uneven stand of sprouts in year 1; few to many small seedlings. Continued invasion expected.	(1)	2	1	BK4	2 or 3	T2	4+	T2-4	$22-27
	(2)	1	1	T2	2 or 3	T2-4	4+	T2-4	21-31
	(3)	3	2	BK4	3 or 4	T2-4	5+	T2-4	22-32
	(4)	1 or 2	2	T2	3	T2-4	4+	T2-4	21-31
	(5)	1 or 2	3+	T2-4	4+	T2-4	5+	T2-4	21-36
No. 5--Fairly continuous, often dense stand of sprouts in year 1; few to many small seedlings. Continued invasion may occur.	(1)	3	1	BK4	2	BK2-6	3+	T2-4	$20-29
	(2)	2	1	BK4-6	2	T2	3+	T2-4	22-29
	(3)	3	2	BK4-6	3	T2	4+	T2-4	22-29
	(4)	1	1	T2	2	T2-4	3+	T2-4	21-31
	(5)	1	2	T2-4	3	T2	4+	T2-4	21-31
	(6)	2	2	T2	3	T2-4	4+	T2-4	21-31
	(7)	1 or 2	3	T2-4	4	T2	5+	T2-4	21-31
	(8)	3	3	T2-4	4	T2-4	5+	T2-4	21-36
	(9)	1 to 3	4+	T2-4	5+	T2-4	6+	T2-4	21-36

DOUGLAS-FIR PLANTATIONS

Little information is available on use of broadcast spray treatments in the Douglas-fir region of California. Consequently, we rely on the Region 6 recommendations made for southwest Oregon.

Site-preparation spraying can be done as recommended for pine plantations in California if the objective is to obtain maximum reduction of woody vegetation ahead of planting. We assume, however, that site-preparation herbicide application on Douglas-fir plantations usually will be limited to selective spraying of tanoak and other hardwood sprouts. This spraying of sprouts actually may become a plantation-care operation if the area is planted soon after slash has been burned.

We assume that satisfactory control of shrubby vegetation in Douglas-fir plantations will be obtained by periodic release spraying at times when the shrubs obviously are competing with the firs for light.

The Region 6 recommendations are briefed into two broad release treatments for trial in California Douglas-fir plantations. One is a spring dormant treatment for control of evergreen brush species. The other is an autumn treatment for control of deciduous brush species; however, it is similar to our recommendation for release spraying in pine plantations and should also give control of evergreen brush species. The two treatments are:

Spring, Dormant Treatment

Date--Early spring, just before vegetative bud burst of Douglas-fir. Usually confined to a 1-month period.

Herbicide--3 pounds, a.e., of low volatile ester per acre.

2,4,5-T	2,4-D	
2 lbs.	1 lb.	-- If ceanothus species are dominant brush species.
1 lb.	2 lbs.	-- If manzanita, tanoak, or madrone are dominant.

Carrier--If either of the two esters we recommend for pine plantations are used, add the commercial formulation to a sufficient volume of water to make 10 gallons total emulsion per acre. Apply it in two helicopter flights of 5 gallons each per acre.

If a questionable commercial formulation is used, mix it with enough surfactant and diesel oil to make a balanced emulsion (see Region 6 handbook) and add to water to make 10 gallons of total emulsion per acre.

Autumn Treatment

Date--During active growth period just before deciduous species form abscission layers--estimated as between September 15 and October 15 in the coast range.

Herbicide--2 to 3 pounds 2,4,5-T low volatile ester per acre.

Carrier--Add herbicide formulation to a sufficient volume of water to make 10 gallons total emulsion per acre. Apply it in two helicopter flights of 5 gallons each.

Add a surfactant and diesel oil to the formulation if needed to make a balanced emulsion, and add to water to make 10 gallons total emulsion per acre.

TANOAK AND OTHER HARDWOOD SPROUTS

Selective spraying of individual clumps is the most effective way of killing sprouting plants of tanoak and other hardwood trees. The large clumps are not readily covered by ground-rig broadcast spraying, and aerial broadcast sprays give only limited control.

Foliage spraying with a backpack mistblower is the recommended treatment. Basal applications of herbicides in oil mixtures are being tested for efficiency and effectiveness compared to the mistblower treatment.

Complete coverage of the dense plant crowns must be obtained for effective kill with a mistblower. Spray all foliage, including the center of the crown, until the leaves appear to be fully wetted. Spraying from only one side of the crown will give incomplete coverage of all except the smallest plants.

A 50/50 mixture of 2,4-D and 2,4,5-T, low volatile esters, is being used, but a higher proportion of 2,4-D in the mixture should be tested. Four pounds, a.e., of the herbicide formulation should be thoroughly mixed with 1 gallon of diesel oil. Mix the herbicide and oil with 8 gallons of water and agitate thoroughly. Apply the spray material with the mistblower adjusted to discharge 1 quart per minute.

Tanoak sprouts that are more than 2 feet in height can be sprayed effectively during all of the plant growing season, from March to October. But first-year sprouts should not be treated until they have grown to about 2 feet in height.

Black oak sprouts have been killed by spraying in July and August when the current year's growth is nearly complete.

Backpack mistblower applications cost $10, or more, per acre for typical stands of about 300 trees per acre. Half of the cost is for chemical. A 3-man crew operating two blowers can work efficiently on most jobs.

FUEL-BREAKS

Special techniques have not been developed for the complete, continuing brush control that will be necessary on fuel-breaks in timber plantations. One reason is that only a few strips have been laid out and designated as future fuel-breaks within or around plantations. At present the new plantation clearings in many places serve temporarily as fuel-breaks. However, long-time intensive management of the plantations that are being established will require breaking of the plantations into small units separated by access ways and fuel-breaks.

Areas to serve as future fuel-breaks should be designated as quickly as management plans can be made, so that brush regrowth on fuel-break areas can be eradicated or held in check before it has grown into dense stands of large woody plants. Early control can be accomplished at a fraction of the cost that will be involved if re-clearing of the brush becomes necessary to reduce woody fuels at a later date.

If brush control with herbicides is started when brush plants are small, preferably within two years after the original brush clearing, the three sprays recommended for pine plantations will give most of the early brush control required on the fuel-break portions of the plantations. Individual-plant spraying of large hardwood sprout clumps or other vigorous shrubby plants also will be needed if such plants occur on the fuel-breaks.

The control of invading brush seedlings that will be required indefinitely on fuel-breaks can be obtained by periodic broadcast spraying with a light rate of 2,4,5-T. After the conifer crowns are several feet above the brush, the herbicide application probably can be made from the ground under the tree canopies.

APPENDIX I

BROADCAST SPRAYING WITH A GROUND-RIG BOOM SPRAYER

Ground-rig spraying should be limited to well cleared areas on which the tractor and boom can be used efficiently with minimum delays caused by obstructions. On smooth terrain a crawler tractor can be operated on slopes up to 40 percent gradient, but wheel tractors are limited to relatively flat land. Rough ground, rocks and steep pitches greatly slow tractor operations and may cause costly breakdowns. Tall, solid brush or tree snags also delay operations or prevent use of a boom. But dead shrub stems that are flexible are not much of a hindrance.

Ground-rig boom sprayers cannot be used to spray old, tall brush. Most of the brush should be well below height of the boom, with few plants above it. The tops of plants within a foot of boom height are not well covered and are not killed by the spray.

Ground-rig sprayers cannot be used for plantation-care spraying over pine trees that are too large; the trees should not be more than 2 or 3 feet in height. The tractor must straddle the trees because rows are too closely spaced or too irregularly spaced for driving between rows.

Project size should be limited to about 200 acres for one ground-rig boom sprayer. If a project is too large the acreage cannot be covered within the optimum spraying period.

A 2-man crew with a small tractor boom sprayer can spray about 20-25 acres a day at typical tractor speeds (table A).

At this daily production ground-rig boom spraying costs about $3.00 per acre, exclusive of chemical.

Table A.--Approximate acres per day sprayed with a ground-rig boom sprayer

Tractor speed	Width of spray swath (feet)									
	8	10	12	14	16	20	22	24	30	33
M.P.H.	Acres Per Day[1]									
1.6	6.5	7.5	9.0	11.0	12.0	15.0	17.5	19.0	23.5	25.0
1.8	7.0	8.5	10.5	12.0	13.5	17.5	19.0	21.0	27.0	28.5
2.0	7.5	9.5	11.5	13.5	15.0	19.0	21.0	23.5	28.5	32.0
2.2	8.0	10.5	12.5	15.0	17.5	21.0	23.5	25.0	32.0	36.5
2.4	9.0	11.5	13.5	16.0	19.0	23.5	25.0	28.5	36.5	40.0
2.6	10.0	12.0	15.0	17.5	20.0	25.0	28.5	31.0	38.0	41.5

---

[1] This assumes that 50 percent of the time is spent in actual spraying. The remainder of the time on a typical operation is spent about as follows: travel, 12 percent; mixing of chemical and loading sprayer, 13 percent; daily sprayer maintenance, 5 percent; training and supervision, 5 percent; and down time for equipment repair and weather, 15 percent.

Parts Of A Ground-Rig Boom Sprayer

The various parts of the sprayer may be mounted directly on a tractor or on a trailer pulled by a tractor. In the most favorable situations a truck can be used to carry or pull the sprayer.

Tractor-mounted sprayers are more maneuverable but have two important disadvantages. Each sprayer is designed for a single tractor model; mounting or demounting of the sprayer takes time and is costly. Trailer-mounted sprayers will do a good job if the trailer is sturdy, It should have heavy duty tires and a protective steel plate under the bed and axle.

Tank.--Two or more supply tanks often are mounted as part of one sprayer. They are satisfactory if only one tank is used at a time, as explained later. Capacity of the tanks, or a single tank, should be near the maximum that can be safely used on the tractor or trailer. One hundred gallons is about the minimum efficient total capacity.

The tanks should be rustproof and easy to clean. A wide mouth aids in loading and cleaning, and a removable strainer is advisable. A rounded tank bottom with a drain in the lowest part is needed.

Strainer.--A large capacity strainer on the line between the supply tank and the pump is essential.

Pump.--Any type of pump that will produce pressures between 10 and 60 p.s.i. can be used. Nylon roller pumps are most common on our boom sprayers. Small pumps with a capacity of about 13 g.p.m. are more than adequate for the sprayer system. But a higher capacity pump may be desired for quickly changing spray material from tank to tank.

The pump may be driven by a power-take-off on the tractor or by a small gasoline engine, usually 5 H.P., mounted as part of the sprayer. Pumps usually are mounted for gravity feed from the supply tank.

Pressure regulator and by-pass.--A disk or diaphram regulator is needed on the line from the pump so that constant pressure can be maintained in the boom. Excess liquid is carried back to the supply tank by a by-pass line. The by-pass is adequate for mixing the chemical emulsion and keeping it agitated during spray operations.

A separate supply line from each tank and a by-pass line to it is needed so that each tank can be used separately. This requires a shut-off valve on the supply line and a valve on the by-pass line for each tank. All lines should be 3/4-inch galvanized steel pipe or non-corrosive tubing. Drain valves or removable plugs are needed in the main supply line.

Boom.--The boom should be in three sections: a center section the width of the tractor or trailer, and two wing booms that can be folded to reduce the overall width of the spray rig. The wing booms should be hinged and suspended in a manner that will allow both horizontal and vertical movement, to prevent breakage of the boom if a solid obstruction is hit. Total width of the boom usually is 20 to 24 feet.

The center boom section can be 1 1/4- or 1 1/2-inch pipe and the wing section can be 3/4- or 1-inch pipe. Each of the three sections should be connected by 3/4-inch oil resistant hose to the main boom supply line, with a shut-off valve ahead of each hose.

A quick-shut-off valve operated with a rope that can be reached by the tractor driver is essential on the main line to the boom, ahead of the three valves to the boom sections.

Nozzles.--The nozzles must be spaced on a boom at regular intervals, but the intervals differ on the different booms. Usually the interval is a multiple of 9, 10, or 12 inches. Spacing can be changed by plugging alternate nozzles.

Each nozzle should produce a flat, fan-shaped spray that gives uniform coverage. We use Tee-Jet nozzles which have replaceable tips of various orifice sizes.

Cluster-nozzles--a group of off-center broadcast nozzles that spread spray over a wide arc--sometimes are used on each end of a short center boom in place of the wing booms. A sprayer of this kind is more maneuverable between trees and brush than is a boom sprayer. However, the broadcast nozzles do not produce uniform coverage, especially when used in a light wind. They are not recommended for our work and should not be used if the spray material can be applied by any other method. They require high volumes of 50-100 gallons per acre and an excess of chemical to allow for spotty coverage.

Calibrating A Ground-Rig Boom Sprayer

The approximate output from a boom sprayer in total gallons per acre can be calculated from:

1. Tractor speed (MPH)--miles per hour.
2. Nozzle spacing (W)--inches between nozzles
3. Nozzle output (GPM)--gallons per minute per nozzle, a function of orifice size and line pressure.

The formula is: gallons per acre = $\frac{5940 \times GPM}{MPH \times W}$

Use of the formula in the field requires several calculations and reference to a manual that shows discharge rates for the various nozzles at different liquid pressures. These calculations are subject to error when done in the field and they give only a theoretical output that must be checked by collecting actual discharge from the nozzle.

We have simplified the procedure and reduced chances for error by calculating, for each speed from 1.0 to 2.5 miles per hour and each common nozzle spacing, the best orifice size and nozzle output for several commonly recommended volumes per acre, as shown in table B (p. 37a--).

To calibrate the sprayer, proceed as follows:

Tractor Speed

1. Drive the sprayer over typical portions of the project area at a speed which prevents excessive jolting and swinging of the boom. Keep the speed at a conservative level--about 2 miles per hour, slower on rough ground but faster on uniformly smooth terrain. Determine the tractor throttle setting that will provide a speed that can be held constant.

2. Set two stakes 100 feet apart on a relatively flat area with soil conditions typical of the area to be sprayed.

3. With the sprayer about half full of water, and the tractor throttle set at the point to be used for the project spraying, drive several times over the marked course. Avoid driving in the same tracks each time. Record the number of seconds required to cover 100 feet.

4. Determine an average speed of travel in terms of seconds per 100 feet and refer to table B to determine the speed to the nearest 0.1 mile per hour.

Nozzle Spacing

Table B shows the best nozzle spacing (in multiples of 9, 10, and 12 inches) to produce a given volume per acre for each tractor speed.

However, a spacing wider than 24 inches between nozzles is not recommended for project work if volume per acre can be increased to allow a narrow nozzle spacing.

Proceed as follows:

1. Measure the number of inches between nozzle tips on the sprayer to be used.

2. Plug alternate nozzles if necessary to obtain the desired nozzle spacing. Nozzles can be plugged by inserting blanks which close off the orifices.

3. If the desired spacing cannot be obtained on the boom being used, the correct calibration can be obtained by calculating from the formula, using table B as a guide.

4. Or, the boom can be replumbed to space the nozzles at the desired intervals.

Gallons per Acre

Table B shows the sprayer calibration for volumes per acre in units of 2.5, 5, or 10 gallons. The nozzle discharge times required to produce intermediate volumes can be determined readily by interpolation.

If the recommended volume per acre cannot be applied with the boom and nozzle sizes on hand, calibrate the sprayer for a higher volume. Add enough water to the recommended mixture per acre to bring it up to the higher volume per acre.

Nozzle Size

Table B shows the largest Tee-Jet orifice that can be used to produce each required nozzle discharge at a liquid pressure between 15 and 40 p.s.i. If either of two orifice sizes can be used, both are shown.

The first numbers on a Tee-Jet nozzle tip (80 or 110) indicate the angle of the spray fan produced at 40 p.s.i. The 110° tips are recommended for wide nozzle spacing, and 80° tips for spacings of 24 inches or less. Tips with a 65° angle also can be used for the narrower spacing. At the low pressures we ordinarily use the fan actually produced is less than the indicated degree of angle.

The second group of numbers on the Tee-Jet tip (.0067, .01, .02, etc.) indicates the expected discharge in gallons per minute at 40 p.s.i.

We prefer spraying with a nozzle spacing and volume per acre that will allow use of .02 orifices which produce little fogging at the nozzle and reduce the chances of nozzle stoppage that is more common with smaller orifices. The larger .03 or .04 nozzle tip can be used if needed to produce high volumes per acre at the narrowest possible nozzle spacing on the boom.

Liquid Pressure

Table B shows the pressures between 15 and 40 p.s.i. that will produce the required nozzle discharge.

Pressures of 20 to 30 p.s.i. are preferred to produce a suitable spray pattern with minimum breaking up of droplets. Lower or higher pressures are used only as required to produce the necessary nozzle discharge.

Do not depend on the pressure gauge reading for proper calibration. It is only approximate. Output can be determined only by collecting discharge from the nozzles. But do check the gauge reading frequently during actual spray operations to determine if major changes in pressure have occurred.

With experience, the liquid pressure can be closely estimated and the performance of individual nozzles checked by observing the angle of each spray fan and the density of liquid discharged from each nozzle.

Nozzle Output

Table B shows for each situation the volume that can be collected in about 30 to 60 seconds and the number of seconds required to collect the given volume. Preliminary calibration can be done by collecting half the volume in half the time, but the volumes and times shown in table B should be used for final calibration.

Proceed as follows to complete the calibration:

1. Select the required size of tip for each nozzle, as shown in table B.
2. Clean the nozzle bodies, screens, and tips and the supply line filter.
3. Start the pump with water in one of the supply tanks, and with the supply line valve and the by-pass valve open on only that one tank.
4. Open the shut-off valve on each of the supply lines to the boom sections.
5. Open the quick-shut-off valve on the main boom supply line, and operate the sprayer until the discharge from each nozzle appears to form a perfect fan.
6. Adjust the pressure regulator until the pressure gauge shows approximately the liquid pressure indicated in table B.

7. Collect the liquid discharged from one nozzle and measure the time required to discharge the volume shown in table B for the desired gallons per acre.

8. Continue to adjust the regulator and measure the nozzle discharge until the average time per given volume is as near as possible to the given time.

9. Check the screens in all nozzles and measure the discharge from each. Replace tips on nozzles not discharging at the desired rate.

Check each day the tractor speed and the discharge of spray emulsion from one or more nozzles on each boom section. Adjust the speed or the pressure if needed to maintain the desired volume per acre.

Check number of gallons used against exact acreage sprayed, allowing for overlap of swaths, to maintain a check on sprayer calibration.

Operating a Ground-Rig Boom Sprayer

Before starting the spray job, adjust the height of the boom so that the fans from the nozzles overlap well above the tops of the brush to be sprayed. Keep the boom sufficiently high to clear obstructions and to prevent the lower end from dragging when the sprayer is tilted on uneven ground.

Drive the tractor at a constant speed. Volume of the spray mixture per acre will be greatly increased if the tractor is slowed in passing over rough spots. Such heavy application on small areas can be tolerated in site-preparation spraying but will cause excessive damage to pines in plantation-care spraying. If the tractor or boom meets a solid obstruction, shut off the boom until the rig has been maneuvered past the obstruction and then resume normal spraying.

Overlap the swaths to obtain full coverage. The spray fan from the end nozzle should overlap the space sprayed by the end nozzle in the preceding swath.

Overlap to give double coverage by the end nozzles is preferable to inadequate overlap. Spacing of swaths usually is judged from observing the tractor tracks in the preceding swath. A more accurate method is to have one man walk behind the boom and set a series of stakes that mark the edge of the swath. The stakes are moved across the area as spraying progresses.

Make sure that the swath overlaps do not occur along tree rows during plantation-care spraying.

Stop spraying if average wind speed is greater than approximately 10 miles per hour. Do not spray when air temperature is below 40° F.

Keep the sprayer system clean, mix the herbicides correctly, maintain the equipment daily, observe all safety precautions, and keep adequate parts, equipment and tools on hand as follows:

Cleaning the Sprayer

1. Check the entire system by pumping water through it before starting a project.

2. Flush the system if needed before starting the project and always at the end of the project. Use a commercial cleaning preparation or water containing 1 percent household ammonia. Let the solution stand in the sprayer a few days, drain, and flush several times with clean water. At the end of the spray season, use a light oil emulsion for the final flushing.

3. Clean the main line strainer by washing in water, and clean the nozzles, tips, and screens in solvent.

4. Partly fill one tank with water and check calibration of the sprayer before loading with herbicide.

Mixing and Loading Herbicides

1. Read the labels on all containers to make sure that only the correct formulations are on hand. Always check the label on each container before using from it.

2. Determine, from the label, the pounds, acid equivalent, of the chemical per gallon of formulation. Most formulations that we now use will contain 4 pounds, a.e., per gallon.

3. Determine the volume of herbicide formulation needed in each tank as follows:

   a. Determine number of acres to be sprayed per tank (5 acres for a 100-gallon tank if spraying is to be at 20 gallons per acre).

   b. Determine pounds, acid equivalent, of chemical required per tank (10 pounds, a.e., for 5 acres to be sprayed at 2 pounds, a.e., per acre).

   c. Determine gallons of herbicide formulation per tank (2 1/2 gallons for 10 pounds, a.e., if the formulation contains 4 pounds, a.e., per gallon).

4. Pour the chemical, or chemicals, required for one tank into a small drum (10-15 gallons) and add the diesel oil if any is required (5 gallons diesel for 5 acres if oil is to be mixed at 1 gallon per acre).

5. Mix the chemical and oil together. Keep dirt and debris out of the chemical and oil at all times. Do not set cans and drums on the ground; work on a truck bed or on a tarpaulin.

6. Fill the first supply tank on the sprayer about one half full of water. Keep supply line and by-pass valves closed.

7. Add the chemical, or chemical and oil mixture, into the tank, pouring through a strainer funnel.

8. Fill the tank to the proper level with water. Use clean water at all times, and strain it into the tank. Keep surface of hoses clean.

9. If supply line and by-pass valves on other tanks are kept closed, the valves on the first tank can be opened, the pump started, and recirculating of the liquid started in the first tank while water is being added to it. Recirculating can be continued while water is being added to the next tank. By-pass the liquid in each tank several times before spraying.

10. Mix chemical and fill other tanks the same as the first tank, and recirculate the liquid in each until the emulsion is thoroughly mixed. Be sure to have the valves open on only one tank at a time.

Do not run the pump dry!

Maintaining the Sprayer

1. Check and service the lubrication systems, battery, air cleaners, etc. on tractor and sprayer each day. Clean the radiator and other parts as needed.

2. Keep plumbing joints and valves well tightened.

3. Clean the main supply line filter each time tanks are filled, or at least once a day.

4. Clean the nozzles, tips, and screens in solvent every one or two days.

5. Observe nozzle spray patterns at all times during spraying and clean screens and tips whenever nozzles are not functioning perfectly.

Extra Parts, Equipment, and Tools

1. Keep a supply of nozzle bodies, nozzle tips, and nozzle strainers to replace parts which may be damaged, worn, or lost.

   Tee-Jet nozzles are used on most sprayers. If not available locally they can be ordered by phone or letter from Harang Engineering Co., P.O. Box 396, San Bruno, California. The nozzle parts and costs are:

   a. Tee-Jet nozzle, complete with specified tip orifice, 1/4" TT (male) or 1/4" T (female), brass - $2.05 each.

   b. Tee-Jet body only, 1/4 TT or 1/4 T, brass - $0.33 each.

   c. No. 1325 Tee-Jet cap only, brass - $0.21 each.

   d. No. 5053 Tee-Jet strainer assembly, brass - $0.46 each.

   e. Tee-Jet spray tip only - $1.05 each. (Keep on hand an adequate supply of commonly used tips - see table B.)

2. The following measuring and mixing equipment will be needed:

   Small drum, approximately 10-15 gallon.

   Open topped 5-gallon cans, graduated in 1-gallon intervals.

   Graduated measures (pint, quart, and gallon).

3. Other pieces of equipment and supplies are:

   Wind meter (GSA No. 6680-833-7010).

   Barrel pump.

   Soap (waterless hand) and rags.

4. Tools needed are:

   Open end wrenches, 11/16" and 13/16" (essential for nozzles).

   Pipe wrenches, 16".

   Screwdrivers and pliers.

   Assorted wrenches, including a socket set.

Observing Safety Precautions

1. Always check herbicide container labels for special precautions in handling. The chemicals we recommend for brush spraying (2,4,5-T and 2,4-D) must be handled with care, but are not particularly hazardous.

2. Avoid prolonged contact of herbicide and oil with the skin. Wash or rinse hands and arms regularly during the day. Any person especially sensitive to the chemical or to the oil used in the emulsions should be removed from a spray project.

3. Always carry an extra supply of water for rinsing or flushing chemical from the skin. Heavy flushing with water is the best emergency first aid if the herbicide enters the eyes or mouth. Get medical attention if continued irritation develops.

4. Always wash with soap and water or with a waterless hand soap preparation before eating.

5. Wash clothes regularly to avoid accumulation of oily substances that may cause skin irritation.

6. Always carry a change of work clothes. They will be needed if excessive amounts of oil or herbicide are spilled on the clothing.

7. Do not wear oil saturated clothing and boots if called to fight fire.

8. Four extra precautions are necessary while working around spray equipment.

    a. Flush accumulations of oil from the sprayer and from truck beds each time the sprayer is loaded.

    b. Do not step on or off of moving equipment, and do not ride on the sprayer unless it is equipped with a proper seat located away from drift of the spray.

    c. Keep clear of the boom. Do not attempt adjustments while the tractor is moving.

    d. Keep clear of emulsion escaping under pressure if a supply line is broken. Let the emulsion waste on the ground if the motor cannot be turned off without taking chances of injury.

APPENDIX II

BROADCAST SPRAYING WITH A HELICOPTER BOOM SPRAYER

These guides are written for contract helicopter spray projects but they also will serve for spray jobs done with fire control helicopters.

Bid invitations for spraying contracts must be prepared well in advance of the actual spraying date--at least 2 to 3 months lead time is desired. If a fire control helicopter is used, the job should be planned far enough in advance to make sure that all necessary equipment will be on hand.

Specify All Contract Requirements

All requirements that will influence bid quotations, and will be enforced by the C.O.R., must be specified in the bid invitations. The items to include are:

1. Small scale map showing location and range in elevation of each project area.
2. Location of clean water supplies in relation to the project area or areas.
3. Location of materials, such as herbicides, to be supplied by the Forest Service.
4. Range of dates within which the project must be completed, and number of days allowed for completion after start of spraying--usually 15 days.
5. Number of days in which spraying must be started after written notification of the required starting date--5 to 7 days.
6. Acreage and volume of spray mixture to be applied per acre on each project area.
7. If the Forest Service is specified as supplying the herbicides, give the general kind of emulsion to be applied on each area. It will be an emulsion of diesel oil and water with 2 to 6 pounds, a.e., of 2,4,5-T and 2,4-D per acre, or it will be an emulsion of water with 2 to 4 pounds, a.e., of 2,4,5-T per acre. If the contractor supplies the oil, specify that it will be diesel oil at 1 gallon per acre.

TABLE B

Calibration of Ground-Rig Boom Sprayer

Tractor Speeds--1.0 to 2.5 miles per hour
Nozzle Spacing--48, 40, 36, 24, 20 or 18 inches
Volumes Per Acre--5, 7.5, 10, 12.5, 15, 20, 25, 30 and 40 gallons
(Nozzle size, liquid pressure, and nozzle output for each volume)

Tractor speed		Nozzle spacing	Volume per acre	Nozzle size	Liquid pressure	Nozzle output	
						Quantity	Time
MPH	Secs/ 100ft.	Ins.	Gals.	TeeJet	PSI	Vol.	Min:Sec.
1.0	68	48	7.5	110-0067	30	½ Pt.	1:02
"	"	"	10.0	110-01	24	"	0:47
1.0	68	40	7.5	110-0067	21	½ Pt.	1:14
"	"	"	10.0	"	40	"	0:56
"	"	"	10.0	110-01	17	"	0:56
"	"	"	12.5	"	27	"	0:45
1.0	68	36	7.5	110-0067	15	½ Pt.	1:23
"	"	"	10.0	"	30	"	1:02
"	"	"	12.5	110-01	22	"	0:50
1.0	68	24	12.5	110-0067	21	½ Pt.	1:14
"	"	"	15.0	"	30	"	1:02
"	"	"	20.0	80-01	25	"	0:47
"	"	"	25.0	"	38	"	0:37
"	"	"	25.0	80-015	17	"	0:37
"	"	"	30.0		26	"	0:31
"	"	"	40.0	80-02	25	1 Pt.	0:47
1.0	68	20	15.0	110-0067	20	½ Pt.	1:14
"	"	"	20.0	80-01	17	"	0:56
"	"	"	25.0	"	26	"	0:45
"	"	"	30.0	"	38	"	0:37
"	"	"	30.0	80-015	17	"	0:37
"	"	"	40.0	"	32	"	0:28
1.0	68	18	15.0	110-0067	15	½ Pt.	1:23
"	"	"	20.0	"	31	"	1:02
"	"	"	25.0	80-01	22	"	0:50
"	"	"	30.0	"	30	"	0:42
"	"	"	40.0	80-015	25	"	0:31
1.1	62	48	7.5	110-0067	40	½ Pt.	0:56
"	"	"	7.5	110-01	17	"	0:56
"	"	"	10.0	"	30	"	0:42

Calibration of Ground-Rig Boom Sprayer--continued

Tractor speed		Nozzle spacing	Volume per acre	Nozzle size	Liquid pressure	Nozzle output	
						Quantity	Time
MPH	Secs/ 100ft.	Ins.	Gals.	TeeJet	PSI	Vol.	Min:Sec
1.1	62	40	7.5	110-0067	25	½ Pt.	1:08
"	"	"	10.0	110-01	21	"	0:51
1.1	62	36	7.5	110-0067	20	½ Pt.	1:15
"	"	"	10.0	"	40	"	0:56
"	"	"	10.0	110-01	17	"	0:56
"	"	"	12.5	"	27	"	0:45
1.1	62	24	12.5	110-0067	25	½ Pt.	1:08
"	"	"	15.0	"	40	"	0:56
"	"	"	15.0	80-01	17	"	0:56
"	"	"	20.0	"	30	"	0:42
"	"	"	25.0	80-015	20	"	0:34
"	"	"	30.0	"	32	"	0:28
"	"	"	40.0	80-02	34	1 Pt.	0:42
"	"	"	40.0	80-03	15	"	0:42
1.1	62	20	12.5	110-0067	16	½ Pt.	1:21
"	"	"	15.0	"	25	"	1:08
"	"	"	20.0	80-01	21	"	0:51
"	"	"	25.0	"	31	"	0:41
"	"	"	30.0	80-015	20	"	0:34
"	"	"	40.0	"	40	"	0:25
"	"	"	40.0	80-02	20	"	0:25
1.1	62	18	15.0	110-0067	20	½ Pt.	1:15
"	"	"	20.0	"	40	"	0:56
"	"	"	20.0	80-01	17	"	0:56
"	"	"	25.0	"	26	"	0:45
"	"	"	30.0	"	36	"	0:38
"	"	"	30.0	80-015	16	"	0:38
"	"	"	40.0	"	32	"	0:28
1.2	57	48	5.0	110-0067	19	½ Pt.	1:17
"	"	"	7.5	110-01	20	"	0:52
1.2	57	40	7.5	110-0067	30	½ Pt.	1:02
"	"	"	10.0	110-01	24	"	0:47
1.2	57	36	7.5	110-0067	24	½ Pt.	1:09
"	"	"	10.0	110-01	20	"	0:52

Table B

Calibration of Ground-Rig Boom Sprayer--continued

Tractor speed		Nozzle spacing	Volume per acre	Nozzle size	Liquid pressure	Nozzle output	
						Quantity	Time
MPH	Secs/ 100ft.	Ins.	Gals.	TeeJet	PSI	Vol.	Min:Sec
1.2	57	24	10.0	110-0067	19	½ Pt.	1:17
"	"	"	12.5	"	31	"	1:02
"	"	"	15.0	80-01	20	"	0:52
"	"	"	20.0	"	34	"	0:39
"	"	"	20.0	80-015	15	"	0:39
"	"	"	25.0	"	25	"	0:31
"	"	"	30.0	"	37	1 Pt.	0:52
"	"	"	30.0	80-02	15	"	0:52
"	"	"	40.0	"	38	"	0:39
"	"	"	40.0	80-03	18	"	0:39
1.2	57	20	12.5	110-0067	21	½ Pt.	1:14
"	"	"	15.0	"	30	"	1:02
"	"	"	20.0	80-01	25	"	0:47
"	"	"	25.0	"	39	"	0:37
"	"	"	25.0	80-015	17	"	0:37
"	"	"	30.0	"	25	"	0:31
"	"	"	40.0	"	40	1 Pt.	0:47
"	"	"	40.0	80-02	20	"	0:47
1.2	57	18	12.5	110-0067	15	½ Pt.	1:23
"	"	"	15.0	"	24	"	1:09
"	"	"	20.0	80-01	20	"	0:52
"	"	"	25.0	"	30	"	0:42
"	"	"	30.0	80-015	19	"	0:35
"	"	"	40.0	"	37	1 Pt.	0:52
"	"	"	40.0	80-02	15	"	0:52
1.3	52+	48	5.0	110-0067	23	½ Pt.	1:11
"	"	"	7.5	110-01	24	"	0:48
1.3	52+	40	7.5	110-0067	37	½ Pt.	0:57
"	"	"	7.5	110-01	16	"	0:57
"	"	"	10.0	"	29	"	0:43
1.3	52+	36	7.5	110-0067	30	½ Pt.	1:03
"	"	"	10.0	110-01	24	"	0:48
1.3	52+	24	10.0	110-0067	23	½ Pt.	1:11
"	"	"	12.5	"	38	"	0:57
"	"	"	12.5	80-01	17	"	0:57
"	"	"	15.0	80-01	24	"	0:48
"	"	"	20.0	"	40	"	0:36
"	"	"	20.0	80-015	18	"	0:36

Calibration of Ground-Rig Boom Sprayer--continued

Tractor speed		Nozzle spacing	Volume per acre	Nozzle size	Liquid pressure	Nozzle output	
						Quantity	Time
MPH	Secs/ 100ft.	Ins.	Gals.	TeeJet	PSI	Vol.	Min:Sec
1.3	52+	24	25.0	80-015	30	½ Pt.	0:29
"	"	"	30.0	80-02	23	1 Pt.	0:48
"	"	"	40.0	80-03	21	"	0:36
1.3	52+	20	12.5	110-0067	24	½ Pt.	1:09
"	"	"	15.0	"	38	"	0:57
"	"	"	15.0	80-01	17	"	0:57
"	"	"	20.0	"	29	"	0:43
"	"	"	25.0	80-015	19	"	0:35
"	"	"	30.0	"	30	"	0:29
"	"	"	40.0	80-02	32	1 Pt.	0:43
1.3	52+	18	12.5	110-0067	19	½ Pt.	1:16
"	"	"	15.0	"	30	"	1:03
"	"	"	20.0	80-01	23	"	0:48
"	"	"	25.0	"	36	"	0:38
"	"	"	25.0	80-015	16	"	0:38
"	"	"	30.0	"	23	"	0:32
"	"	"	40.0	80-02	23	1 Pt.	0:48
1.4	49	48	5.0	110-0067	27	½ Pt.	1:06
"	"	"	7.5	110-01	28	"	0:44
1.4	49	40	5.0	110-0067	17	½ Pt.	1:20
"	"	"	7.5	110-01	20	"	0:53
1.4	49	36	7.5	110-0067	35	½ Pt.	0:59
"	"	"	7.5	110-01	15	"	0:59
"	"	"	10.0	110-01	28	"	0:44
1.4	49	24	10.0	110-0067	27	½ Pt.	1:06
"	"	"	12.5	80-01	20	"	0:53
"	"	"	15.0	"	28	"	0:44
"	"	"	20.0	80-015	21	"	0:33
"	"	"	25.0	"	35	"	0:27
"	"	"	30.0	80-02	30	1 Pt.	0:44
"	"	"	40.0	80-03	23	"	0:33
1.4	49	20	10.0	110-0067	17	½ Pt.	1:20
"	"	"	12.5	"	29	"	1:04
"	"	"	15.0	80-01	19	"	0:53
"	"	"	20.0	"	33	"	0:40

Table B

Calibration of Ground-Rig Boom Sprayer--continued

Tractor speed		Nozzle spacing	Volume per acre	Nozzle size	Liquid pressure	Nozzle output	
						Quantity	Time
MPH	Secs/ 100ft.	Ins.	Gals.	TeeJet	PSI	Vol.	Min:Sec
1.4	49	20	25.0	80-015	25	½ Pt.	0:31
"	"	"	30.0	"	35	"	0:27
"	"	"	40.0	80-02	37	1 Pt.	0:40
1.4	49	18	12.5	110-0067	23	½ Pt.	1:11
"	"	"	15.0	"	35	"	0:59
"	"	"	15.0	80-01	15	"	0:59
"	"	"	20.0	"	27	"	0:44
"	"	"	25.0	"	40	"	0:36
"	"	"	25.0	80-015	16	"	0:36
"	"	"	30.0	"	27	"	0:30
"	"	"	40.0	80-02	30	1 Pt.	0:44
1.5	45+	48	5.0	110-0067	30	½ Pt.	1:02
1.5	45+	40	5.0	110-0067	20	½ Pt.	1:14
"	"	"	7.5	110-01	22	"	0:50
1.5	45+	36	5.0	110-0067	15	½ Pt.	1:23
"	"	"	7.5	110-01	18	"	0:55
1.5	45+	24	7.5	110-0067	16	½ Pt.	1:22
"	"	"	10.0	"	30	"	1:02
"	"	"	12.5	80-01	22	"	0:50
"	"	"	15.0	"	32	"	0:41
"	"	"	20.0	80-015	25	"	0:31
"	"	"	25.0	"	40	1 Pt.	0:50
"	"	"	25.0	80-02	20	"	0:50
"	"	"	30.0	"	35	"	0:41
"	"	"	30.0	80-03	16	"	0:41
"	"	"	40.0	"	26	"	0:31
"	"	"	40.0	80-04	15	"	0:31
1.5	45+	20	10.0	110-0067	20	½ Pt.	1:14
"	"	"	12.5	"	35	"	0:59
"	"	"	12.5	80-01	15	"	0:59
"	"	"	15.0	"	22	"	0:50
"	"	"	20.0	"	39	"	0:37
"	"	"	20.0	80-015	17	"	0:37
"	"	"	25.0	"	27	"	0:30
"	"	"	30.0	"	40	1 Pt.	0:50

Calibration of Ground-Rig Boom Sprayer--continued

Tractor speed		Nozzle spacing	Volume per acre	Nozzle size	Liquid pressure	Nozzle output	
						Quantity	Time
MPH	Secs/ 100ft.	Ins.	Gals.	TeeJet	PSI	Vol.	Min:Sec
1.5	45+	20	30.0	80-02	20	1 Pt.	0:50
"	"	"	40.0	"	40	"	0:37
"	"	"	40.0	80-03	19	"	0:37
1.5	45+	18	10.0	110-0067	15	½ Pt.	1:23
"	"	"	12.5	"	26	"	1:06
"	"	"	15.0	80-01	18	"	0:55
"	"	"	20.0	"	30	"	0:42
"	"	"	25.0	80-015	21	"	0:33
"	"	"	30.0	"	32	"	0:28
"	"	"	40.0	80-02	34	1 Pt.	0:42
"	"	"	40.0	80-03	15	"	0:42
1.6	43	48	5.0	110-0067	36	½ Pt.	0:58
"	"	"	5.0	110-01	16	"	0:58
1.6	43	40	5.0	110-0067	24	½ Pt.	1:10
"	"	"	7.5	110-01	25	"	0:46
1.6	43	36	5.0	110-0067	19	½ Pt.	1:17
"	"	"	7.5	110-01	20	"	0:52
1.6	43	24	7.5	110-0067	19	½ Pt.	1:17
"	"	"	10.0	"	36	"	0:58
"	"	"	10.0	80-01	16	"	0:58
"	"	"	12.5	"	27	"	0:45
"	"	"	15.0	"	35	"	0:39
"	"	"	15.0	80-015	15	"	0:39
"	"	"	20.0	"	30	"	0:29
"	"	"	25.0	80-02	27	1 Pt.	0:46
"	"	"	30.0	"	38	"	0:39
"	"	"	30.0	80-03	18	"	0:39
"	"	"	40.0	"	28	"	0:29
"	"	"	40.0	80-04	17	"	0:29
1.6	43	20	10.0	110-0067	19	½ Pt.	1:10
"	"	"	12.5	"	40	"	0:56
"	"	"	12.5	80-01	17	"	0:56
"	"	"	15.0	"	24	"	0:46
"	"	"	20.0	80-015	19	"	0:35
"	"	"	25.0	"	32	"	0:28
"	"	"	30.0	"	27	1 Pt.	0:46
"	"	"	40.0	80-03	21	"	0:35

Table B

Calibration of Ground-Rig Boom Sprayer--continued

Tractor speed		Nozzle spacing	Volume per acre	Nozzle size	Liquid pressure	Quantity	Time
MPH	Secs/ 100ft.	Ins.	Gals.	TeeJet	PSI	Vol.	Min:Sec
1.6	43	18	10.0	100-0067	19	½ Pt.	1:17
"	"	"	12.5	"	31	"	1:02
"	"	"	15.0	80-01	20	"	0:52
"	"	"	20.0	"	36	"	0:38
"	"	"	20.0	80-015	16	"	0:38
"	"	"	25.0	"	25	"	0:31
"	"	"	30.0	"	37	"	0:26
"	"	"	30.0	80-02	15	"	0:26
"	"	"	40.0	"	39	1 Pt.	0:38
"	"	"	40.0	80-03	18	"	0:38
1.7	40	48	5.0	110-01	17	½ Pt.	0:55
1.7	40	40	5.0	110-0067	27	½ Pt.	1:06
"	"	"	7.5	110-01	28	"	0:44
1.7	40	36	5.0	110-0067	21	½ Pt.	1:13
"	"	"	7.5	100-01	18	"	0:49
1.7	40	24	7.5	110-0067	22	½ Pt.	1:12
"	"	"	10.0	80-01	17	"	0:55
"	"	"	12.5	"	33	"	0:44
"	"	"	15.0	"	40	"	0:36
"	"	"	15.0	80-015	18	"	0:36
"	"	"	20.0	"	32	"	0:28
"	"	"	25.0	80-02	30	1 Pt.	0:44
"	"	"	30.0	80-03	20	"	0:36
"	"	"	40.0	"	32	"	0:28
"	"	"	40.0	80-04	18	"	0:28
1.7	40	20	10.0	110-0067	27	½ Pt.	1:06
"	"	"	12.5	80-01	20	"	0:52
"	"	"	15.0	"	28	"	0:44
"	"	"	20.0	80-015	21	"	0:33
"	"	"	25.0	"	37	"	0:26
"	"	"	25.0	80-02	15	"	0:26
"	"	"	30.0	"	30	1 Pt.	0:44
"	"	"	40.0	80-03	22	"	0:33
1.7	40	18	10.0	110-0067	21	½ Pt.	1:13
"	"	"	12.5	"	37	"	0:58
"	"	"	12.5	80-01	16	"	0:58

Calibration of Ground-Rig Boom Sprayer--continued

Tractor speed		Nozzle spacing	Volume per acre	Nozzle size	Liquid pressure	Nozzle output	
						Quantity	Time
MPH	Secs/ 100ft.	Ins.	Gals.	TeeJet	PSI	Vol.	Min:Sec
1.7	40	18	15.0	80-01	23	½ Pt.	0:49
"	"	"	20.0	"	39	"	0:37
"	"	"	20.0	80-015	17	"	0:37
"	"	"	25.0	"	30	"	0:29
"	"	"	30.0	80-02	21	1 Pt.	0:49
"	"	"	40.0	"	40	"	0:37
"	"	"	40.0	80-03	19	"	0:37
1.8	38	48	5.0	110-01	20	½ Pt.	0:52
1.8	38	40	5.0	110-0067	31	½ Pt.	1:02
1.8	38	36	5.0	110-0067	24	½ Pt.	1:09
"	"	"	7.5	110-01	25	"	0:46
1.8	38	24	7.5	110-0067	25	½ Pt.	1:08
"	"	"	10.0	80-01	20	"	0:52
"	"	"	12.5	"	32	"	0:41
"	"	"	15.0	80-015	20	"	0:34
"	"	"	20.0	"	37	"	0:26
"	"	"	20.0	80-02	15	"	0:26
"	"	"	25.0	"	35	1 Pt.	0:41
"	"	"	25.0	80-03	16	"	0:41
"	"	"	30.0	"	22	"	0:34
"	"	"	40.0	"	37	1 Qt.	0:52
"	"	"	40.0	80-04	21	"	0:52
1.8	38	20	7.5	110-0067	16	½ Pt.	1:24
"	"	"	10.0	"	31	"	1:02
"	"	"	12.5	80-01	22	"	0:50
"	"	"	15.0	"	30	"	0:42
"	"	"	20.0	80-015	25	"	0:31
"	"	"	25.0	"	40	1 Pt.	0:50
"	"	"	25.0	80-02	20	"	0:50
"	"	"	30.0	"	35	"	0:41
"	"	"	30.0	80-03	16	"	0:41
"	"	"	40.0	"	26	"	0:31
"	"	"	40.0	80-04	15	"	0:31
1.8	38	18	10.0	110-0067	24	½ Pt.	1:09
"	"	"	12.5	80-01	18	"	0:55
"	"	"	15.0	"	26	"	0:46

Table B

Calibration of Ground-Rig Boom Sprayer--continued

Tractor speed		Nozzle spacing	Volume per acre	Nozzle size	Liquid pressure	Nozzle output	
						Quantity	Time
MPH	Secs/ 100ft.	Ins.	Gals.	TeeJet	PSI	Vol.	Min:Sec
1.8	38	18	20.0	80-015	19	½ Pt.	0:35
"	"	"	25.0	"	32	"	0:28
"	"	"	30.0	80-02	27	1 Pt.	0:46
"	"	"	40.0	80-03	21	"	0:35
1.9	36	48	5.0	110-01	23	½ Pt.	0:49
1.9	36	40	5.0	110-0067	35	½ Pt.	0:59
"	"	"	5.0	110-01	15	"	0:59
1.9	36	36	5.0	110-0067	28	½ Pt.	1:05
"	"	"	7.5	110-01	29	"	0:43
1.9	36	24	7.5	110-0067	28	½ Pt.	1:05
"	"	"	10.0	80-01	23	"	0:49
"	"	"	12.5	"	35	"	0:39
"	"	"	12.5	80-015	15	"	0:39
"	"	"	15.0	"	22	"	0:33
"	"	"	20.0	80-02	21	1 Pt.	0:49
"	"	"	25.0	"	38	"	0:39
"	"	"	25.0	80-03	18	"	0:39
"	"	"	30.0	"	23	"	0:33
"	"	"	40.0	80-04	23	1 Qt.	0:49
1.9	36	20	7.5	110-0067	18	½ Pt.	1:18
"	"	"	10.0	"	35	"	0:59
"	"	"	10.0	80-01	15	"	0:59
"	"	"	12.5	"	24	"	0:47
"	"	"	15.0	"	35	"	0:39
"	"	"	15.0	80-015	15	"	0:39
"	"	"	20.0	"	27	"	0:30
"	"	"	25.0	80-02	25	1 Pt.	0:47
"	"	"	30.0	"	38	"	0:39
"	"	"	30.0	80-03	18	"	0:39
"	"	"	40.0	"	27	"	0:30
"	"	"	40.0	80-04	16	"	0:30
1.9	36	18	10.0	110-0067	28	½ Pt.	1:05
"	"	"	12.5	80-01	20	"	0:52
"	"	"	15.0	"	29	"	0:43
"	"	"	20.0	80-015	21	"	0:33
"	"	"	25.0	"	37	"	0:26

Calibration of Ground-Rig Boom Sprayer--continued

Tractor speed		Nozzle spacing	Volume per acre	Nozzle size	Liquid pressure	Nozzle output	
						Quantity	Time
MPH	Secs/ 100ft.	Ins.	Gals.	TeeJet	PSI	Vol.	Min:Sec
1.9	36	18	25.0	80-02	15	½ Pt.	0:26
"	"	"	30.0	"	32	1 Pt.	0:43
"	"	"	40.0	80-03	23	"	0:33
2.0	34	48	5.0	110-01	25	½ Pt.	0:46
2.0	34	40	5.0	110-0067	40	½ Pt.	0:56
"	"	"	5.0	110-01	17	"	"
2.0	34	36	5.0	110-0067	30	½ Pt.	1:02
2.0	34	24	7.5	110-0067	30	½ Pt.	1:02
"	"	"	10.0	80-01	25	"	0:46
"	"	"	12.5	"	38	"	0:37
"	"	"	12.5	80-015	17	"	0:37
"	"	"	15.0	"	26	"	0:31
"	"	"	20.0	80-02	27	1 Pt.	0:46
"	"	"	25.0	"	40	"	0:37
"	"	"	25.0	80-03	19	"	0:37
"	"	"	30.0	"	26	"	0:31
"	"	"	30.0	80-04	15	"	0:31
"	"	"	40.0	"	26	1 Qt.	0:46
2.0	34	20	7.5	110-0067	21	½ Pt.	1:14
"	"	"	10.0	"	40	"	0:56
"	"	"	10.0	80-01	17	"	0:56
"	"	"	12.5	"	27	"	0:45
"	"	"	15.0	"	38	"	0:37
"	"	"	15.0	80-015	17	"	0:37
"	"	"	20.0	"	32	"	0:28
"	"	"	25.0	80-02	29	1 Pt.	0:45
"	"	"	30.0	"	40	"	0:37
"	"	"	30.0	80-03	19	"	0:37
"	"	"	40.0	"	32	"	0:28
"	"	"	40.0	80-04	18	"	0:28
2.0	34	18	7.5	110-0067	16	½ Pt.	1:22
"	"	"	10.0	"	30	"	1:02
"	"	"	12.5	80-01	22	"	0:50
"	"	"	15.0	"	32	"	0:41
"	"	"	20.0	80-015	25	"	0:31
"	"	"	25.0	"	40	1 Pt.	0:50

Table B

Calibration of Ground-Rig Boom Sprayer--continued

Tractor speed		Nozzle spacing	Volume per acre	Nozzle size	Liquid pressure	Nozzle output	
						Quantity	Time
MPH	Secs/ 100ft.	Ins.	Gals.	TeeJet	PSI	Vol.	Min:Sec
2.0	34	18	25.0	80-02	20	1 Pt.	0:50
"	"	"	30.0	"	35	"	0:41
"	"	"	40.0	80-03	26	"	0:31
"	"	"	40.0	80-04	15	"	0:31
2.1	32+	48	5.0	110-01	28	½ Pt.	0:44
2.1	32+	40	5.0	110-01	20	½ Pt.	0:53
2.1	32+	36	5.0	110-0067	35	½ Pt.	0:59
"	"	"	5.0	110-01	15	"	0:59
2.1	32+	24	7.5	110-0067	35	½ Pt.	0:59
"	"	"	7.5	80-01	15	"	0:59
"	"	"	10.0	"	28	"	0:44
"	"	"	12.5	80-015	19	"	0:35
"	"	"	15.0	"	30	"	0:29
"	"	"	20.0	80-02	30	1 Pt.	0:44
"	"	"	25.0	80-03	21	"	0:35
"	"	"	30.0	"	28	"	0:29
"	"	"	30.0	80-04	17	"	0:29
"	"	"	40.0	"	27	1 Qt.	0:44
2.1	32+	20	7.5	110-0067	24	½ Pt.	1:12
"	"	"	10.0	80-01	20	"	0:53
"	"	"	12.5	"	30	"	0:42
"	"	"	15.0	"	40	"	0:36
"	"	"	15.0	80-015	18	"	0:36
"	"	"	20.0	"	35	1 Pt.	0:53
"	"	"	25.0	80-02	34	"	0:42
"	"	"	25.0	80-03	15	"	0:42
"	"	"	30.0	"	21	"	0:35
"	"	"	40.0	"	35	1 Qt.	0:53
"	"	"	40.0	80-04	20	"	0:53
2.1	32+	18	7.5	110-0067	19	½ Pt.	1:18
"	"	"	10.0	"	35	"	0:59
"	"	"	10.0	80-01	15	"	0:59
"	"	"	12.5	"	24	"	0:47
"	"	"	15.0	"	35	"	0:39
"	"	"	15.0	80-015	15	"	0:39

Calibration of Ground-Rig Boom Sprayer--continued

Tractor speed		Nozzle spacing	Volume per acre	Nozzle size	Liquid pressure	Nozzle output	
						Quantity	Time
MPH	Secs/ 100ft.	Ins.	Gals.	TeeJet	PSI	Vol.	Min:Sec
2.1	32+	18	20.0	80-015	27	½ Pt.	0:30
"	"	"	25.0	80-02	25	1 Pt.	0:47
"	"	"	30.0	"	38	"	0:39
"	"	"	30.0	80-03	18	"	0:39
"	"	"	40.0	"	27	"	0:30
"	"	"	40.0	80-04	16	"	0:30
2.2	31	48	5.0	110-01	30	½ Pt.	0:42
2.2	31	40	5.0	110-01	21	½ Pt.	0:51
2.2	31	36	5.0	110-0067	40	½ Pt.	0:56
"	"	"	5.0	110-01	17	"	0:56
2.2	31	24	7.5	110-0067	40	½ Pt.	0:56
"	"	"	7.5	80-01	17	"	0:56
"	"	"	10.0	"	30	"	42
"	"	"	12.5	80-015	20	"	34
"	"	"	15.0	"	32	"	28
"	"	"	20.0	80-02	34	1 Pt.	42
"	"	"	20.0	80-03	15	"	42
"	"	"	25.0	"	22	"	34
"	"	"	30.0	"	32	"	28
"	"	"	30.0	80-04	18	"	28
"	"	"	40.0	"	31	1 Qt.	42
2.2	31	20	7.5	110-0067	26	½ Pt.	1:07
"	"	"	10.0	80-01	21	"	51
"	"	"	12.5	"	31	"	41
"	"	"	15.0	80-015	20	"	34
"	"	"	20.0	"	37	"	26
"	"	"	20.0	80-02	15	"	26
"	"	"	25.0	"	35	1 Pt.	41
"	"	"	25.0	80-03	16	"	41
"	"	"	30.0	"	22	"	34
"	"	"	40.0	"	38	1 Qt.	51
"	"	"	40.0	80-04	21	"	51
2.2	31	18	7.5	110-0067	20	½ Pt.	1:16
"	"	"	10.0	"	40	"	56
"	"	"	10.0	80-01	17	"	56
"	"	"	12.5	"	26	"	45
"	"	"	15.0	"	36	"	38
"	"	"	15.0	80-015	16	"	38

Table B

Calibration of Ground-Rig Boom Sprayer--continued

Tractor speed		Nozzle spacing	Volume per acre	Nozzle size	Liquid pressure	Nozzle output	
						Quantity	Time
MPH	Secs/ 100ft.	Ins.	Gals.	TeeJet	PSI	Vol.	Min:Sec
2.2	31	18	20.0	80-015	32	½ Pt.	28
"	"	"	25.0	80-02	29	1 Pt.	45
"	"	"	30.0	"	39	"	38
"	"	"	30.0	80-03	18	"	38
"	"	"	40.0	"	31	"	28
"	"	"	40.0	80-04	18	"	28
2.3	29+	40	5.0	110-01	23	½ Pt.	0:48
2.3	29+	36	5.0	110-01	19	½ Pt.	0:54
2.3	29+	24	5.0	110-0067	17	½ Pt.	1:20
"	"	"	7.5	80-01	19	"	0:54
"	"	"	10.0	"	33	"	0:40
"	"	"	12.5	80-015	23	"	0:32
"	"	"	15.0	"	34	"	0:27
"	"	"	20.0	80-02	37	1 Pt.	0:40
"	"	"	25.0	80-03	24	"	0:32
"	"	"	30.0	"	33	1 Qt.	0:54
"	"	"	30.0	80-04	19	"	0:54
"	"	"	40.0	"	35	"	0:40
2.3	29+	20	7.5	110-0067	29	½ Pt.	1:06
"	"	"	10.0	80-01	33	"	0:48
"	"	"	12.5	"	35	"	0:39
"	"	"	12.5	80-015	15	"	0:39
"	"	"	15.0	"	22	"	0:33
"	"	"	20.0	80-02	23	1 Pt.	0:48
"	"	"	25.0	"	37	"	0:39
"	"	"	25.0	80-03	17	"	0:39
"	"	"	30.0	"	24	"	0:32
"	"	"	40.0	80-04	24	1 Qt.	0:48
2.3	29+	18	7.5	110-0067	22	½ Pt.	1:12
"	"	"	10.0	80-01	19	"	0:54
"	"	"	12.5	"	29	"	0:43
"	"	"	15.0	80-015	18	"	0:36
"	"	"	20.0	"	35	"	0:27
"	"	"	25.0	80-02	32	1 Pt.	0:43
"	"	"	30.0	80-03	20	"	0:36
"	"	"	40.0	"	33	1 Qt.	0:54
"	"	"	40.0	80-04	20	"	0:54

Calibration of Ground-Rig Boom Sprayer--continued

Tractor speed		Nozzle spacing	Volume per acre	Nozzle size	Liquid pressure	Nozzle output	
						Quantity	Time
MPH	Secs/ 100ft.	Ins.	Gals.	TeeJet	PSI	Vol.	Min:Sec
2.4	28	40	5.0	110-01	25	½ Pt.	0:46
2.4	28	36	5.0	110-01	20	½ Pt.	0:52
2.4	28	24	5.0	110-0067	18	½ Pt.	1:18
"	"	"	7.5	80-01	20	"	0:52
"	"	"	10.0	"	35	"	0:39
"	"	"	10.0	80-015	15	"	0:39
"	"	"	12.5	"	25	"	0:31
"	"	"	15.0	"	37	"	0:26
"	"	"	20.0	80-02	38	1 Pt.	0:39
"	"	"	20.0	80-03	18	"	0:39
"	"	"	25.0	"	26	"	0:31
"	"	"	25.0	80-04	15	"	0:31
"	"	"	30.0	80-03	33	1 Qt.	0:54
"	"	"	30.0	80-04	19	"	0:54
"	"	"	40.0	"	35	"	0:39
2.4	28	20	7.5	110-0067	30	½ Pt.	1:02
"	"	"	10.0	80-01	26	"	0:46
"	"	"	12.5	"	38	"	0:37
"	"	"	12.5	80-015	17	"	0:37
"	"	"	15.0	"	25	"	0:31
"	"	"	20.0	80-02	27	1 Pt.	0:46
"	"	"	25.0	"	40	"	0:37
"	"	"	25.0	80-03	19	"	0:37
"	"	"	30.0	"	25	"	0:31
"	"	"	30.0	80-04	15	"	0:31
"	"	"	40.0	"	26	1 Qt.	0:46
2.4	28	18	7.5	110-0067	25	½ Pt.	1:08
"	"	"	10.0	80-01	20	"	0:52
"	"	"	12.5	"	31	"	0:41
"	"	"	15.0	80-015	20	"	0:34
"	"	"	20.0	"	37	"	0:26
"	"	"	20.0	80-02	15	"	0:26
"	"	"	25.0	"	35	1 Pt.	0:41
"	"	"	25.0	80-03	16	"	0:41
"	"	"	30.0	"	21	"	0:34
"	"	"	40.0	"	36	1 Qt.	0:52
"	"	"	40.0	80-04	21	"	0:52

Table B

Calibration of Ground-Rig Boom Sprayer--continued

Tractor speed		Nozzle spacing	Volume per acre	Nozzle size	Liquid pressure	Nozzle output	
						Quantity	Time
MPH	Secs/ 100ft.	Ins.	Gals.	TeeJet	PSI	Vol.	Min:Sec
2.5	27	40	5.0	110-01	26	½ Pt.	0:45
2.5	27	36	5.0	110-01	22	½ Pt.	0:50
2.5	27	24	5.0	110-0067	21	½ Pt.	1:14
"	"	"	7.5	80-01	22	"	0:50
"	"	"	10.0	"	38	"	0:37
"	"	"	10.0	80-015	17	"	0:37
"	"	"	12.5	"	28	"	0:30
"	"	"	15.0	"	40	"	0:25
"	"	"	15.0	80-02	17	"	0:25
"	"	"	20.0	"	40	1 Pt.	0:37
"	"	"	20.0	80-03	19	"	0:37
"	"	"	25.0	"	27	"	0:30
"	"	"	25.0	80-04	16	"	0:30
"	"	"	30.0	80-03	40	1 Qt.	0:50
"	"	"	30.0	80-04	22	"	0:50
"	"	"	40.0	"	40	"	0:37
2.5	27	20	7.5	110-0067	33	½ Pt.	1:00
"	"	"	10.0	80-01	27	"	0:45
"	"	"	12.5	"	40	"	0:36
"	"	"	12.5	80-015	18	"	0:36
"	"	"	15.0	"	28	"	0:30
"	"	"	20.0	80-02	29	1 Pt.	0:45
"	"	"	25.0	80-03	20	"	0:36
"	"	"	30.0	"	27	"	0:30
"	"	"	30.0	80-04	16	"	0:30
"	"	"	40.0	"	26	1 Qt.	0:45
2.5	27	18	7.5	110-0067	27	½ Pt.	1:06
"	"	"	10.0	80-01	22	"	0:50
"	"	"	12.5	"	33	"	0:40
"	"	"	15.0	80-015	22	"	0:33
"	"	"	20.0	"	40	1 Pt.	0:50
"	"	"	20.0	80-02	20	"	0:50
"	"	"	25.0	"	36	"	0:40
"	"	"	25.0	80-03	16	"	0:40
"	"	"	30.0	"	22	"	0:33
"	"	"	40.0	"	40	1 Qt.	0:50
"	"	"	40.0	80-04	22	"	0:50

8. If the contractor is specified as furnishing the chemical and oil, give the exact quantities per acre of each and the total gallons per acre of emulsion to be applied on each area. Specify that each chemical must be either butoxy ethanol ester or propylene glycol butyl ether ester.

9. Requirements of helicopter, pilots, etc.

10. The acceptable kind of spray system on the helicopter--

    a. A boom system (rotating centrifugal devices will not be acceptable for the kinds of emulsion to be applied).

    b. An output per nozzle between 0.22 and 1.22 gpm at a pressure between 15 and 30 p.s.i.

    c. A flying speed between 35 and 60 m.p.h.

    d. An effective swath width no greater than twice the boom length, measured from tip to tip.

11. Mixing equipment with adequate agitation.

12. Equipment to be furnished by the Forest Service, such as radio communication and transportation for employees.

13. Personnel to be furnished by the Forest Service, such as flagmen and their supervisor, C.O.R., etc.

Keep Each Project To A Feasible Size

Limit each project to the acreage that readily can be sprayed within the time limit specified in the contract--usually 15 days.

Maximum size of project is determined by the average number of gallons of spray material that a helicopter can apply per day with normal delays from unfavorable weather and other factors. The estimated average is about 1,000 gallons per day.

At 15 gallons per acre, the average production is estimated at about 70 acres a day, which limits feasible size of project to 750-1,000 acres. At 10 gallons per acre, the maximum size of project may be 1,000-1,200 acres.

The minimum project size for efficient operation is 300-500 acres. Several small areas can be combined to make a project of this size.

Remove Obstruction From The Spray Areas

All spray areas should be free of snags and excess live trees that will prevent safe, efficient, and uniform spray application.

Arrange for removal of snags and sale of any unwanted merchantable trees well in advance of the spraying date.

Map And Mark The Spray Areas

Make a small sketch map showing location of the area, or areas, in relation to roads, cleared lines, or natural features that are easily identified.

Break large project areas into small natural spraying units, each no larger than approximately 200 acres. Accurately determine the acreage of each unit in advance of spraying. These acreage figures will be needed during the spraying operation to check the spray volume being applied.

Show locations of all power lines or telephone lines within or adjacent to the project area.

Select tentative heliport locations and mark them on the map. Heliports easily accessible to water-hauling trucks and located above the areas to be sprayed are preferred. But final selection of the heliports should be made with the contractor on the ground.

If needed, mark key location points on the ground just prior to spraying by use of large cloth or foil panels. Show these points on the sketch map.

Plan a reconnaissance flight with the pilot prior to starting the spray operations to acquaint him with area boundaries and locations of all hazards. If additional temporary markers are needed, they can be placed during the reconnaissance flight by dropping small paper bags loaded with lime.

Purchase The Proper Herbicides

The Forest Service should provide the herbicide for contract helicopter projects, for several reasons:

1. This can assure that the correct herbicide is delivered and checked ahead of starting spray operations, so that spraying is not delayed by last minute delivery of the wrong material.

2. Herbicides can be purchased through the Regional consolidated bid contract at a price usually lower than the cost to a helicopter spray contractor. The price can be as much as $1.00 per gallon lower.
3. Most important, final selection of the herbicide rate per acre on each area can be made just preceding the spray application when size and density of brush regrowth can best be judged.

Decide Swath Width And Flight Pattern

The effective swath width and the pattern of flying must be decided with the contractor on the ground before calibration of the spray system is checked.

Swath Width

The contractor probably will suggest for his particular helicopter spray system an effective swath over which the spray material is assumed to be uniformly distributed. Commonly this swath width will be about twice the length of the boom.

Accept a swath width no more than 2.0 times the boom length measured from tip to tip of the boom as specified in the contract bid invitation.

Distribution of spray material across the swath can be roughly checked by catching the droplets on a narrow strip of butcher paper or adding machine tape laid on the ground at a right angle to the flight line. A small amount of Rhodamine B dye, or similar coloring agent, is needed in the emulsion to produce easily observed droplet marks. No simple means is available for accurately measuring distribution of the actual chemical being applied.

Observations, photos, and limited experimental data indicate, for the droplet sizes and air speeds that we use, much more than half of the spray mixture falls directly under the boom or in a strip about 1.2 times the boom length. The remainder of the material is unevenly spread outside of this strip. It may feather out for some distance on the downwind side.

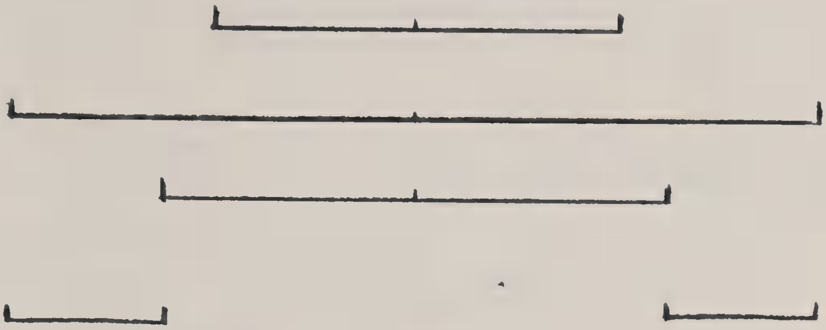
We assume that a typical swath will be somewhat as follows:

Boom length--40'

Swath width--80'

Area of heavy coverage--50'

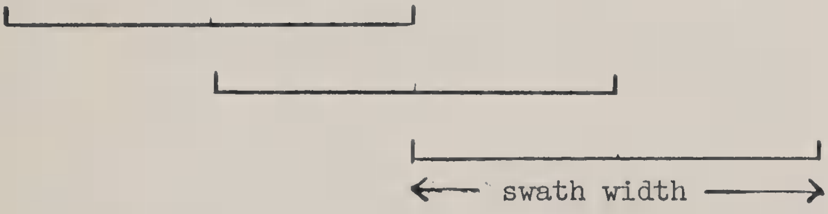
Areas of light uneven
coverage--15' each



Flight Pattern

The spray material should be applied by double coverage. In each flight swath apply one-half of the total volume recommended per acre. Calibrate the sprayer to apply 2 pounds, a.e., of chemical in 7.5 gallons emulsion per acre in each swath if the recommended total treatment is 4 pounds in 15 gallons.

The best way to obtain double coverage is to overlap the swaths 50 percent. However, adequate flagging is required to guide the flight lines. Double coverage by overlapping swaths will develop the following pattern:



Cross flying is an alternate method of double coverage that is less desirable. Half of the spray material is applied by flying in one direction and half by flying at a right angle to the first flight lines. The swaths are not overlapped.

Double coverage by overlapping swaths in one direction has important advantages over cross flying, as follows:

1. Spraying is completed on a unit within a few minutes. With cross flying, the second half of the spray mixture may be applied on the unit a few hours or days after the first half, which possibly will reduce the effect of the total treatment.

2. Concentration of spray material in the center half of the swath is compensated for to some extent in overlapped swaths, if the flight lines are accurately located by flagmen. In contrast, cross flying tends to produce a "checkerboard" pattern.

3. Flagmen need to be moved across each unit only once.

The direction of flight lines on each unit must be mutually decided by the contractor and the C.O.R. Terrain, obstructions at the ends of possible flight lines, or locations of heliports may dictate the direction of flying.

If possible, the flight lines should be at a right angle to windrows so that flagmen can measure distance between swaths with greatest accuracy.

The speed and height of flying are mutually decided, but they are primarily the responsibility of the contractor, within the limits specified in the bid invitation. The height should be 25 to 50 feet above the vegetation on easy terrain.

Check Calibration Of The Helicopter Spray System

Proper calibration of the spray system is the responsibility of the contractor, or the operator of a fire control helicopter. But the C.O.R. should check the calibration to see if speed, nozzle size, and liquid pressure are within acceptable limits. He should check the calibration and actual application rate periodically during the spraying operation.

Volume in gallons per acre (GPA) is determined by:

S--Swath width in feet,

MPH--Helicopter speed in miles per hour, and

GPM--Total boom discharge in gallons per minute.

To determine the total boom discharge required to apply a given volume per acre one formula that can be used is:

GPM = GPA x S x MPH x .002

For example, to apply 7.5 gallons per acre in a swath 60 feet wide at a speed of 50 miles per hour, the total boom discharge should equal 7.5 x 60 x 50 x .002 = 45 gallons per minute. See table C.

Or, GPM = Acres per minute x GPA

Table C gives acres per minute for different swath widths and speeds. Intermediate values can be interpolated.

To determine the output per nozzle required to produce the necessary total boom discharge, divide the number of nozzles on the boom into the GPM discharge of the total boom.

For example, if the boom has 45 nozzles and the total boom discharge must be 45 GPM, the output of each nozzle must be 1.00 gallons per minute.

Table C.--Total boom discharges required to apply various volumes per acre for given swath widths, flying speeds, and acres sprayed per minute.

Swath width ft.	Flying speed m.p.h.	Spraying rate acres/min.	To apply a given volume (gallons/acre) of --			
			2.5	5	7.5	10
			Total boom discharge (gallons/min.) must be --			
60	35	4.2	10.5	21.0	31.5	42.0
	40	4.8	12.0	24.0	36.0	48.0
	45	5.4	13.5	27.0	40.5	54.0
	50	6.0	15.0	30.0	45.0	60.0
	55	6.6	16.5	33.0	49.5	66.0
	60	7.2	18.0	36.0	54.0	72.0
70	35	4.9	12.3	24.5	36.8	49.0
	40	5.6	14.0	28.0	42.0	56.0
	45	6.3	15.8	31.5	47.3	63.0
	50	7.0	17.5	35.0	52.5	70.0
	55	7.7	19.3	38.5	57.8	77.0
	60	8.4	21.0	42.0	63.0	84.0
80	35	5.6	14.0	28.0	42.0	56.0
	40	6.4	16.0	32.0	48.0	64.0
	45	7.2	18.0	36.0	54.0	72.0
	50	8.0	20.0	40.0	60.0	80.0
	55	8.8	22.0	44.0	66.0	88.0
	60	9.6	24.0	48.0	72.0	96.0
90	35	6.3	15.8	31.5	47.3	63.0
	40	7.2	18.0	36.0	54.0	72.0
	45	8.1	20.3	40.5	60.8	81.0
	50	9.0	22.5	45.0	67.5	90.0
	55	9.9	24.8	49.5	74.3	99.0
	60	10.8	27.0	54.0	81.0	108.0
100	35	7.0	17.5	35.0	52.5	70.0
	40	8.0	20.0	40.0	60.0	80.0
	45	9.0	22.5	45.0	67.5	90.0
	50	10.0	25.0	50.0	75.0	100.0
	55	11.0	27.5	55.0	82.5	110.0
	60	12.0	30.0	60.0	90.0	120.0

Table D shows, for one make of nozzle, the nozzle size and p.s.i. required for each of various outputs from 0.22 to 1.22 gallons per minute per nozzle. The helicopter system may be fitted with another make of nozzle with similar outputs.

Within the above output range, the larger nozzle orifices are preferred. At low p.s.i. they produce large droplets, which reduces loss from drift and volatilization. Break up of the droplets by wind shear at the nozzle orifice can be reduced by placing nozzles on the boom so that they point backward and downward.

After the required GPM discharge from the boom has been calculated and the boom has been fitted with the required number and size of nozzles, the spray system can be calibrated on the ground. The time required to discharge a given volume of water can be recorded while the pump is operating at full capacity, as follows:

1. Outputs of individual nozzles can be checked if desired by collecting the discharge from each of several nozzles located along the full length of the boom. Refer to table D to determine the number of seconds required to discharge a given volume per nozzle. With a bucket under each nozzle to be checked, turn on the spray system for the given time. Measure the amount collected from each nozzle. Replace any nozzles or orifice tips that are not functioning properly. Adjust the pressure and remeasure until the average discharge per nozzle is correct. Or change the number of nozzles on the boom so that the calculated required discharge per nozzle equals the actual discharge.

2. Discharge from the entire boom should be checked by loading a known volume of water into the helicopter tanks and recording the time required to discharge this volume. If this volume is the same as the required GPM already calculated for the boom, it should be discharged in exactly one minute. If some other volume is used (say 50 gallons) and is discharged in a recorded time (say 1.2 minutes), the discharge rate can be easily calculated (41.7 GPM for this example). Adjust the pressure or number of nozzles as needed until the actual discharge rate is approximately the same as the calculated GPM for the entire boom.

The calibration of the helicopter spray system should be checked periodically while it is actually applying the spray material, as follows:

Table D.--Number of seconds required to discharge a given volume per nozzle for each--g.p.m. output per nozzle, nozzle size and pressure (one make of nozzle).

Output per nozzle	Nozzle size orifice	Nozzle size core	Pressure	Discharge rate		Output per nozzle	Nozzle size orifice	Nozzle size core	Pressure	Discharge rate	
G.p.m.	No.	No.	P.s.i.	Secs.	Vol.	G.p.m.	No.	No.	P.s.i.	Secs.	Vol.
.22	D4	45	15	34	pt.	.57	D5	46	23	53	$\frac{1}{2}$ gal.
.23	"	"	17	33	"	.58	"	"	23	52	"
.24	"	"	18	31	"	.59	"	"	24	51	"
.25	"	"	20	30	"	.60	"	"	25	50	"
.26	"	"	22	29	"	.61	"	"	26	49	"
.27	"	"	23	28	"	.62	"	"	27	48	"
.28	"	"	25	27	"	.63	"	"	27	48	"
.29	"	"	27	26	"	.64	"	"	28	47	"
.30	"	"	28	25	"	.65	"	"	29	46	"
.31	"	"	30	24	"	.66	"	"	30	45	""
.32	D5	45	20	23	"	.67	D6	46	15	45	"
.33	"	"	21	23	"	.68	"	"	15	44	"
.34	"	"	23	22	"	.69	"	"	16	43	"
.35	"	"	24	21	"	.70	"	"	16	43	"
.36	"	"	25	21	"	.71	"	"	17	42	"
.37	"	"	26	20	"	.72	"	"	17	42	"
.38	"	"	28	39	qt.	.73	"	"	18	41	"
.39	"	"	30	38	"	.74	"	"	18	41	"
.40	D4	46	21	38	"	.75	"	"	19	40	"
.41	"	"	22	37	"	.76	"	"	19	39	"
.42	"	"	23	36	"	.77	"	"	20	39	"
.43	"	"	24	35	"	.78	"	"	20	38	"
.44	"	"	25	34	"	.79	"	"	21	38	"
.45	"	"	26	33	"	.80	"	"	21	37	"
.46	"	"	28	33	"	.81	"	"	22	37	"
.47	"	"	29	32	"	.82	"	"	22	37	"
.48	"	"	30	31	"	.83	"	"	23	36	"
.49	D5	46	16	31	"	.84	"	"	23	36	"
.50	"	"	17	30	"	.85	"	"	24	35	"
.51	"	"	18	29	"	.86	"	"	24	35	"
.52	"	"	19	29	"	.87	"	"	25	34	"
.53	"	"	19	28	"	.88	"	"	26	34	"
.54	"	"	20	28	"	.89	"	"	26	34	"
.55	"	"	21	27	"	.90	"	"	27	33	"
.56	"	"	22	27	"	.91	"	"	27	33	"

Table D.--Number of seconds required to discharge a given volume per nozzle for each--g.p.m. output per nozzle, nozzle size and pressure (one make of nozzle) (cont.).

Output per nozzle	Nozzle size orifice	Nozzle size core	Pressure	Discharge rate	
G.p.m.	No.	No.	P.s.i.	Secs.	Vol.
.92	D6	46	28	33	$\frac{1}{2}$ gal.
.93	"	"	29	32	"
.94	"	"	29	32	"
.95	"	"	30	32	"
.96	D7	46	18	31	"
.97	"	"	19	31	"
.98	"	"	20	31	"
.99	"	"	20	30	"
1.00	"	"	21	30	"
1.01	"	"	21	59	gal.
1.02	"	"	22	59	"
1.03	"	"	22	58	"
1.04	"	"	23	58	"
1.05	"	"	23	57	"
1.06	"	"	23	57	"
1.07	"	"	24	56	"
1.08	"	"	24	56	"
1.09	"	"	25	55	"
1.10	"	"	25	55	"
1.11	"	"	25	54	"
1.12	"	"	26	54	"
1.13	"	"	26	53	"
1.14	"	"	27	53	"
1.15	"	"	27	52	"
1.16	"	"	28	52	"
1.17	"	"	28	51	"
1.18	"	"	28	51	"
1.19	"	"	29	50	"
1.20	"	"	29	50	"
1.21	"	"	30	50	"
1.22	"	"	30	49	"

1. Calculate the time required to discharge a tank load of known volume: Determine acres per load (a 75-gallon load will cover 10 acres at 7.5 gallons per acre). Determine the number of acres per minute being sprayed, from table C (50 m.p.h., spraying an 80-foot swath, covers 8 acres per minute). Calculate the minutes and seconds per load (10 acres at 8 acres per minute equals 1.25 minutes, or 1 minute and 15 seconds per load).

2. Determine the length of time during which spray material actually is being discharged from the nozzles while one load is being sprayed. The spray system may be turned on and off two or more times per load. Thus, a stopwatch is essential for making the measurements. Repeat the time record at least twice, and determine the actual application rate.

Report the calibration results to the contract helicopter operator, or make the calibration checks jointly with a representative of the contractor. If the application rate differs significantly (more than about 5 percent) from the desired rate, the entire spray system should be checked and cleaned. Then, rechecking of the calibration may show that adjustments are needed in the liquid pressure, number of nozzles, or speed of flying.

Provide Adequate Equipment And Personnel

Water-hauling and mixing equipment, often combined into a single unit, is provided by the contractor on contract spray projects. It also is provided by some operators of fire control helicopters. But on many projects where the helicopter is paid by the hour, the Forest Service must provide the hauling and mixing equipment or rent it from a spray contractor.

Make sure that hauling equipment or water storage facilities on the job are adequate to provide the maximum supply of clean water that may be used in one day. While the average volume sprayed per day may be about 1,000 gallons, the volume used during the best spraying days may be 3,000 to 5,000 gallons.

Mixing equipment should have a high capacity pump for quick mixing of herbicide and water through the by-pass system and for rapid loading of the helicopter tanks. A metering device is needed for recording volumes pumped into the helicopter.

Provide complete radio contact between the C.O.R., flagmen and supervisor, pilot, and the heliport so that the job can be kept running smoothly and accurately. This has proved to be a most important element in obtaining good spray application.

The Forest Service should provide the flagmen and their supervisor along with transportation on all project areas where flagmen can be used. Provide at least three flagmen. Men with experience in pacing distances on rough terrain and around obstacles are needed. If possible, these men should be personnel who will gain from the experience on a herbicide spraying job. Such men will be conscientious and capable of using good judgment. Arrange for overtime pay for the off-hour work necessary on a spray project.

Make sure that the necessary equipment is on hand for making the desired field measurements. Weather instruments are essential. A stopwatch is required. Other equipment may be needed for collecting and measuring nozzle outputs.

Maintain A Check Of All Operations

1. Work out with the contractor a system for using flagmen to mark the flight lines. Make sure that the lines are kept straight, with proper spacing between lines. Determine ahead of actual flying the number of swaths required to cover each portion of a spray unit and adjust spacing of flight lines as needed to obtain the correct number of swaths.

   On units where flagmen cannot be used, such as small, steep clear-cut blocks, station a man where he can judge the uniformity of spray application and can notify the contractor by radio of any necessary changes in the flight pattern.

2. Maintain an official diary record of all phases of the spraying job. Keep the daily flight record on a special form.

   Record the total volume of emulsion applied on each small spray unit. This serves as a check on spacing of flight lines and on calibration of the spray system.

   Record the weather conditions--wind velocity and direction, air temperature, and relative humidity--at intervals no longer than one-half hour, or when noticeable changes occur. Under marginal weather conditions records will be needed for almost all flights.

   Observe and record the way in which the spray is being applied--height of flying above the ground, effect of wind on the spray pattern,and spray drift, and other factors considered of importance.

3. Stop the spray operations when weather conditions become unfavorable--average wind velocity above approximately 5 m.p.h., wind too gusty, or air temperature above approximately 70° F.

4. Check the contractor's equipment for adequacy and soundness. Bring all apparent deficiencies in equipment condition or in safety practices to the attention of the contractor and notify the proper Forest Service officials of the actions taken.

   Check regularly for leaks in the spray equipment and for nozzle dripping. Have all observed leaks repaired before spraying is continued.

5. Check all mixing operations to see that the proper herbicides in the correct amounts are being used. Observe whether the emulsions are stable and are being maintained by adequate agitation.

   The following procedure assures adequate mixing and agitation of the 2,4-D and 2,4,5-T herbicide formulations that we now are using:

   a. Thoroughly mix the commercial herbicide formulation with the oil, if oil is being added to the spray mixture. If no oil is added, the formulation can be poured straight. Surfactants need not be added to the presently recommended formulations.

   b. Add water to the tank until about half the desired volume is in the tank.

   c. Start the agitator or the pump and by-pass system.

   d. Add the correct amount of the commercial formulation, or the formulation and oil mixture.

   e. Add the remaining amount of water to bring the mixture up to the desired volume and continue the agitation until throughly mixed.

   f. Reagitate before and during the time the mixture is drawn from the mix tank.

   g. Agitate the mixture during spraying.

6. Become thoroughly familiar with the safety precautions connected with all phases of the spraying operation. Train the participating Forest Service personnel and make sure that the precautions are observed at all times.

7. Maintain radio contact with a base station so that accidents or emergencies can be reported immediately. This contact also is required by the contractor so that he can make emergency orders for equipment or repairs.

Prepare A Final Project Report

All information on calibration of equipment, volumes applied on individual spray units, weather conditions during spraying of each unit, and other pertinent points should be summarized as the project progresses. Put this information into an overall report when the project is completed.

The C.O.R. also should make a personal evaluation of the following points:

1. Materials and equipment furnished by the contractor, particularly equipment condition.
2. Familiarity of the contractor with the contract requirements.
3. Efficiency and cooperativeness of the contractor.
4. Questions or disputes between contractor and C.O.R., and how resolved.
5. Suitability of contractor for future awards. Be specific if any shortcomings are mentioned.
6. Adequacy of information in this handbook and suggestions for improvement.

GPO 971-472

FORM 6200-8 (1-64)
UNITED STATES GOVERNMENT
Memorandum

Department of Agriculture—Forest Service
San Francisco, California 94111

TO : Forest Supervisors, Region 5

File No. 2470

FROM : Paul E. Neff, Chief, Division of Timber Management

Date: April 18, 1967

SUBJECT: Silvicultural Practices - Reforestation

Your reference:

This is an amendment to the handbook "Use of Herbicides on Timber Plantations" published in September 1965, by Region 5 and the Pacific Southwest Forest and Range Experiment Station. Purpose of such amendments is to keep the brush control recommendations up to date until the handbook is reissued. Current recommendations are based on observations of recent administrative study plots and larger projects.

The amendment is being sent at this time to help you plan your spray jobs for the coming fiscal year. Copies should be attached to the reverse side of the cover of all of your copies of the September 1965, handbook.

Current Recommendations

The brush control recommendations given in the handbook, starting on page 18, should be followed except on areas where sprouting Sierra chinkapin or tanoak are the major problem species.

Sierra Chinkapin

If chinkapin is the main problem species on a bulldozed area, the brush regrowth should not be sprayed at the end of the first growing season as recommended in the handbook. Early spraying has only limited effects on small sprouting chinkapin. More efficient control of the overall brush stand can be obtained if the start of spraying is delayed another year.

> Recommendation: Plant during the spring following bulldozing. Wait until the second fall after planting; then spray with 2,4,5-T at a rate of 2 or 3 pounds, acid equivalent, per acre. Repeat this treatment the next fall, or wait one more year. After two more years apply a third spray if needed for adequate brush control.

If both sprouting bitter cherry and chinkapin are the dominant species on a bulldozed area, spraying should start before the cherry plants have developed new root systems. In this case, spray at the end of the first full growing season -- but before leaves of the young cherry plants start turning yellow -- as recommended in the handbook. Use a 50/50 mixture of 2,4-D and 2,4,5-T. Plant during the following spring. Apply the release

Spray two years after the site preparation spray, to allow adequate growth of chinkapin sprouts. Apply a second release spray two years later, if needed.

Tanoak

The following discussion applies to Douglas-fir plantations in the North Coast Zone.

Observations indicate that brush control sprays can be delayed until competition for light has developed. Early individual - plant spraying of young tanoak clumps with a backpack mistblower, as recommended in the handbook, appears too costly for the degree of control that is obtained.

An alternate method that appears to be more practical is broadcast spraying by helicopter after the tanoak clumps have grown taller and developed relatively open crowns that the spray will penetrate. This stage is reached 4 to 6 years after clearing or slash burning. Follow the herbicide recommendations on pages 23 and 24 of the handbook. Repeat the release spray as needed.

For control of tanoak sprouts in pine plantations in the Westside Sierra Zone, follow directions in the handbook until more specific recommendations can be made.

Site Preparation By Broadcast Burning and Spraying

After removing brush by burning, two applications of herbicides before planting have not proved necessary. See page 19, item 4a of the handbook. An area can be planted during the next spring after the first site-preparation spray.

> Recommendation: Allow one growing season after burning before applying a site-preparation spray. After an early spring burn in April or March, spray about September 1. After a summer or fall burn, spray in August of the next year. Plant pine seedlings the next spring after spraying. Apply a release spray -- 2 to 4 pounds 2,4,5-T per acre -- either the next fall or one year later. Apply a second release spraying as needed.

Site Preparation By Bulldozing And Spraying

The effective brush control being obtained from herbicide spraying makes it possible to prepare sites without deep bulldozing. Brush topgrowth can be removed by blading at the ground surface and leaving brush roots and burls in the soil. Regrowth can be controlled by spraying, as on burned areas. The total spray job should be no more expensive than required in many cases for control of brush seedlings on deeply bulldozed areas.

Shallow dozing has the advantages of leaving the topsoil in place and making clean windrows that can be readily burned. Costs of shallow bulldozing plus spraying should be less than for typical deep bulldozing and spraying.

> Recommendation: Remove brush by shallow dozing, and control the vigorous brush regrowth by the same spray program as used after burning.

Guides to Timing Release Spraying Over Ponderosa Pine

Our handbook and other literature state that the safest period for spraying over pines is after the pine buds are fully formed and hardened. District personnel ask how to recognize this growth stage. Following are the best guides that are available.

Observe development of pine buds throughout the summer, starting in early July. The buds develop at different rates in different years, depending on seasonal growing conditions. When first formed the buds are reddish with green scales. As hardening progresses the buds become darker brown, and finally all, or most, of the scales also become brown; the buds become firmer and the resin on the bud dries.

The buds on all trees in a plantation do not harden at the same time. Time the spraying for the date when the majority of vigorous trees have hardened terminal buds. Do not delay spraying because of a few stragglers.

If the terminal bud is hardened and dormant, spraying can be done even though some lateral buds on the leader have broken dormancy and grown 1 or 2 inches.

Observations to date indicate that ponderosa and Jeffrey pine plantations in the Sierra can be sprayed about September 1. This spraying date gives the best chance of avoiding extremely cold weather soon after spraying; which appears to be a major cause of excessive tree damage. The September 1 spray date also has given effective brush kill, much better than spraying later during cold weather. Early spraying is essential for control of young bitter cherry and similar decidious species.

Jeffrey pine seedlings have been much less susceptible to spray damage than have ponderosa seedlings.

More Guides To Helicopter Calibration

The handbook (pages 40-44) recommends spraying in parallel, overlapping swaths. This is called double flying, with half the chemical applied in each flight, because the swath is considered to be twice the width of the boom. For example, to apply 10 gallons per acre with a 40-foot boom, the swath is considered to be 80 feet wide, the boom output is computed to apply 5 gallson per acre over the 80-foot swath, but flight lines are only 40 feet apart -- thus, 10 gallons per acre are applied.

In the above example, the 80-foot swath was chosen because spray operators commonly calculate their coverage at about twice the length of the boom. But in actual practice the "double coverage" calculations have proven slightly confusing to both the operators and District personnel.

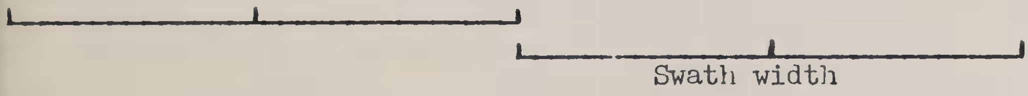
More recent studies indicate that the effective swath is approximately the boom length plus ten feet -- thus the effective swath width of a 40-foot boom is 50 feet and a 50-foot boom is 60 feet. Studies also indicate that single coverage with adequate controls gives sufficiently even distribution with less flying time. To apply 10 gallons per acre with a 40-foot boom, the swath is considered to be 50-feet wide, the boom output is computed to apply 10 gallons per acre over a 50-foot swath, and flight lines are 50-feet apart -- thus 10 gallons per acre are applied.

We assume that a typical swath is somewhat as follows:

Boom length 40'

Effective swath width 50'

The flight pattern will have the following pattern:



Recommendations:

1. Consider swath width to be the boom length plus 10-feet.

2. Single fly parallel swaths wherever possible to use adequate flagmen control.

    a. Space flight lines at a distance apart equal to length of the boom plus 10-feet.

    b. Calibrate the boom output to discharge the <u>total desired volume per acre</u> over the swath.

    c. <u>Calibration Example</u>: To apply 10 gallons per acre using a helicopter with a 40' boom and a flying speed of 50 mph. From revised Table C (next page) the total boom discharge necessary is determined to be 50 gallons/minute based on an effective swath width of 50-feet.

3. Double fly, by cross flying at right angles only where evenly spaced parallel flight lines cannot be flown. The need for this type of flying should be very limited.

a. Space flight lines at a distance apart equal to length of the boom plus 10 feet.

b. Calibrate the boom output to discharge only <u>one-half the desired volume per acre</u> over the swath.

c. Calibration Example: To apply 10 gallons per acre with one-half the volume to be applied on each flight using a helicopter with a 40' boom and a flying speed of 40 mph. Using revised Table C (next page) the total boom discharge required is determined to be 20 gallons/minute based on an effective swath width of 50 feet.

Table C.--Total boom discharges required to apply various volumes per acre for given swath widths, flying speeds, and acres sprayed per minute.

Boom length	Swath width	Flying speed	Spraying rate	To apply a given volume (gallons/acre of --		
				5	10	15
ft.	ft.	m.p.h.	acres/min.	Total boom discharge (gallons/min.) must be --		
30	40	35	2.8	14.0	28.0	42.0
		40	3.2	16.0	32.0	48.0
		45	3.6	18.0	36.0	54.0
		50	4.0	20.0	40.0	60.0
		55	4.4	22.0	44.0	66.0
		60	4.8	24.0	48.0	72.0
35	45	35	3.2	16.0	32.0	48.0
		40	3.6	18.0	36.0	54.0
		45	4.0	20.0	40.0	60.0
		50	4.5	22.5	45.0	67.5
		55	5.0	25.0	50.0	75.0
		60	5.4	27.0	54.0	81.0
40	50	35	3.5	17.5	35.0	52.5
		40	4.0	20.0	40.0	60.0
		45	4.5	22.5	45.0	67.5
		50	5.0	25.0	50.0	75.0
		55	5.5	27.5	55.0	82.5
		60	6.0	30.0	60.0	90.0
45	55	35	3.8	19.0	38.0	57.0
		40	4.4	22.0	44.0	66.0
		45	5.0	25.0	50.0	75.0
		50	5.5	27.5	55.0	82.5
		55	6.0	30.0	60.0	90.0
		60	6.6	33.0	66.0	99.0
50	60	35	4.2	21.0	42.0	63.0
		40	4.8	24.0	48.0	72.0
		45	5.4	27.0	54.0	81.0
		50	6.0	30.0	60.0	90.0
		55	6.6	33.0	66.0	99.0
		60	7.2	36.0	72.0	108.0

Paul E Neff

FORM 6200-8 (1/64)

UNITED STATES GOVERNMENT

Memorandum

Department of Agriculture—Forest Service
San Francisco, California 94111

TO : Forest Supervisors, R-5

File No. 2470

FROM : Chas. A. Connaughton, Regional Forester, R-5,
By

Date: September 30, 1965

SUBJECT: Silvicultural Practices

Your reference:

This third report on "USE OF HERBICIDES ON TIMBER PLANTATIONS" is the last of the series. It brings together conclusions to date from the tests conducted by Ken Estes and Jay Bentley over the past three years.

Your staff can use this report as an interim handbook for herbicide application in site preparation and plantation care. Sufficient copies are being included for working tools on all Ranger Districts. Additional copies are available in this office.

Ken Estes is presently available for technical assistance in planning and conducting herbicide spray projects. Contact him through the Forest Supervisor, Lassen National Forest. Jay Bentley may also be contacted for on-the-ground advice through the Director, Pacific Southwest Forest and Range Experiment Station, P.O. Box 245, Berkeley, California.

The April 1, 1964 report should be discarded.

Attachment

A. Morse

cc: Ranger District Dist. - 2 ea.

FORM 6200-8 (1-64)
UNITED STATES GOVERNMENT

Memorandum

Department of Agriculture—Forest Service
San Francisco, California 94111

TO : Forest Supervisors, Region 5

File No. 2470

FROM : Paul E. Neff, Chief, Division of Timber Management

Date: April 18, 1967

SUBJECT: Silvicultural Practices - Reforestation

Your reference:

This is an amendment to the handbook "Use of Herbicides on Timber Plantations" published in September 1965, by Region 5 and the Pacific Southwest Forest and Range Experiment Station. Purpose of such amendments is to keep the brush control recommendations up to date until the handbook is reissued. Current recommendations are based on observations of recent administrative study plots and larger projects.

The amendment is being sent at this time to help you plan your spray jobs for the coming fiscal year. Copies should be attached to the reverse side of the cover of all of your copies of the September 1965, handbook.

Current Recommendations

The brush control recommendations given in the handbook, starting on page 18, should be followed except on areas where sprouting Sierra chinkapin or tanoak are the major problem species.

Sierra Chinkapin

If chinkapin is the main problem species on a bulldozed area, the brush regrowth should not be sprayed at the end of the first growing season as recommended in the handbook. Early spraying has only limited effects on small sprouting chinkapin. More efficient control of the overall brush stand can be obtained if the start of spraying is delayed another year.

> Recommendation: Plant during the spring following bulldozing. Wait until the second fall after planting; then spray with 2,4,5-T at a rate of 2 or 3 pounds, acid equivalent, per acre. Repeat this treatment the next fall, or wait one more year. After two more years apply a third spray if needed for adequate brush control.

If both sprouting bitter cherry and chinkapin are the dominant species on a bulldozed area, spraying should start before the cherry plants have developed new root systems. In this case, spray at the end of the first full growing season -- but before leaves of the young cherry plants start turning yellow -- as recommended in the handbook. Use a 50/50 mixture of 2,4-D and 2,4,5-T. Plant during the following spring. Apply the release